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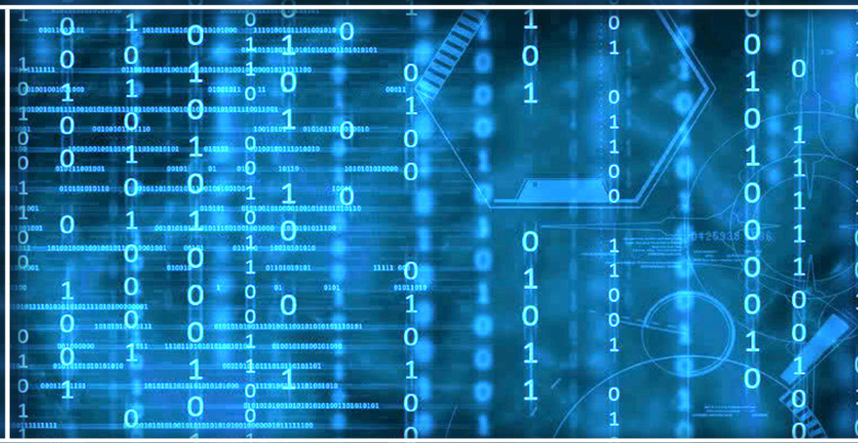

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Editorial Preface

From the Desk of Managing Editor…

It may be difficult to imagine that almost half a century ago we used computers far less sophisticated than current home desktop computers to put a man on the moon. In that 50 year span, the field of computer science has exploded.

Computer science has opened new avenues for thought and experimentation. What began as a way to simplify the calculation process has given birth to technology once only imagined by the human mind. The ability to communicate and share ideas even though collaborators are half a world away and exploration of not just the stars above but the internal workings of the human genome are some of the ways that this field has moved at an exponential pace.

At the International Journal of Advanced Computer Science and Applications it is our mission to provide an outlet for quality research. We want to promote universal access and opportunities for the international scientific community to share and disseminate scientific and technical information.

We believe in spreading knowledge of computer science and its applications to all classes of audiences. That is why we deliver up-to-date, authoritative coverage and offer open access of all our articles. Our archives have served as a place to provoke philosophical, theoretical, and empirical ideas from some of the finest minds in the field.

We utilize the talents and experience of editor and reviewers working at Universities and Institutions from around the world. We would like to express our gratitude to all authors, whose research results have been published in our journal, as well as our referees for their in-depth evaluations. Our high standards are maintained through a double blind review process.

We hope that this edition of IJACSA inspires and entices you to submit your own contributions in upcoming issues. Thank you for sharing wisdom.

Thank you for Sharing Wisdom!

Kohei Arai
Editor-in-Chief
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A New Approach of e-Commerce Web Design for Accessibility based on Game Accessibility in Chinese Market

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***Abstract*—China is the largest e-commerce market globally, with a share of more than 40% of the total value of e-commerce transactions in the world, down from just 1% a decade ago. The Chinese are the most used electronic payment, ordering services, and watching videos on smart devices worldwide. The study of e-commerce is one of the branches of business administration established electronically through the use of Internet networks, which aim to carry out buying and selling operations. With the popularity of e-commerce, people from more and more backgrounds are using e-commerce websites and apps, but among these users, some people are unable to use these apps/websites or have barriers to use them. Accessibility design enables anyone (regardless of ability, for example, Color-blind) to successfully navigate, understand and use some applications. The accessibility design is widely used in video games, which can give guidance to the e-commerce accessibility design. This study will analyze five well-known e-commerce websites worldwide and the consumption habits of people with barriers to use from the perspective of accessible design to suggest two new concepts of accessible design methods based on game accessibility and web accessibility to make these e-commerce websites/apps more suitable with the user habits of the particular group.**

***Keywords*—e-Commerce; accessibility design; color-blind; game accessibility**

I. Background

A. The Importance of Accessibility Design to e-Commerce Websites

Designing a professional online store for our business in an innovative way that provides a good user experience for our customers will undoubtedly build a different and strong image in front of consumers and increase their confidence in your services and products. China e-commerce has made remarkable achievements, increasing impact and penetration on the economic, social, cultural, and other fields, and has become a new driving force for economic growth. e-Commerce has also become an indispensable part of the daily life of the Chinese people. As a virtual place for businesses and consumers to communicate, e-commerce websites provide consumers with an excellent online consumption experience, including visual and auditory stimuli. With these advantages, those e-commerce websites encourage consumers to spend actively and give consumers a good experience. [1]. However, the vast majority of e-commerce sites are not explicitly designed for people with disabilities. The users of an e-commerce website should be all consumers, and it should provide more help to these disabled users. Because of their physical reasons, people with disabilities are subject to many restrictions when using e-commerce websites, so they cannot get a complete experience, undermining people with disabilities in using e-commerce websites.

B. Difficulties in using e-Commerce Websites for People with Disabilities

According to the 12th five-year Development Program data for the cause of disabled people in China, the total number of disabled people in China is about 85 million, which means in every 16 Chinese people, there's one has a disability. [2]. There is no doubt that it is challenging for people with disabilities to use e-commerce sites without accessibility design, even if they have some assistive devices, such as voice recognition and auxiliary input. To fundamentally solve the problem that it is difficult for people with disabilities to use, it is necessary to carry out the barrier-free design of e-commerce websites. However, the vast majority of websites are not specially designed for the disabled so far. The mainstream dynamic design and color layout of e-commerce sites are not effective enough for visually impaired people, making it difficult to obtain product information and purchase products.

C. Game Accessibility Solutions

As an entertainment tool that gives users powerful sensory impact, the accessibility design in video games is targeted and integrated. The integrated accessibility settings can be used in other fields, especially vision and hearing settings. Take "The Last of Us: Part II" for example; Naughty Dog studio designed more than 60 accessibility settings in one particular block called "Accessibility" shown in Fig. 1. The rules for classification and some methods such as "Magnification and visual aids" can inspire the accessibility design in e-commerce.

D. Objectives and Motivations

From the previous A and B part, the Chinese e-market has a large number of users with disabilities. Many of them have problems using e-commerce website, how to increase the user experience for this group of users is the question need to be solved in this paper. As a solution to the problem, better e-commerce using the system can increase the user experience directly; this system should consider different types of disabilities and put other solutions in an integrated environment. Designing an integrated setting or system for e-commerce accessibility is the purpose of this research; various tools and ideas are used to achieve this. Since the online website nowadays requires more on images, UI, and interaction quality, which are the core fields of video game design or game accessibility, it is possible to transport the experience of game accessibility to e-commerce accessibility. In total, this research aims at the e-market of users with a disability, trying to design an integrated system for e-commerce accessibility based on the experience from game accessibility; this system is the ideal solution to solve the using problems from users with disabilities.

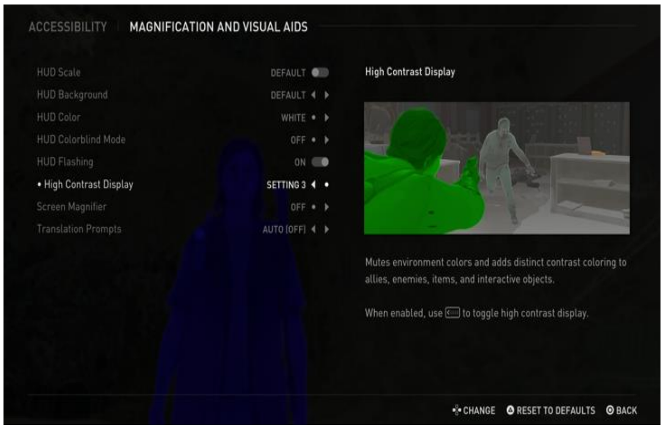

Fig. 1. Accessibility Setting in "The Last of US: Part II" (The Last of US: Part II Accessibility Introduction Page).

II. Related Work

Since the same research material could not be found, the researcher will analyze similar studies, namely on game accessibility, to inspire the design. Game accessibility is an approach commonly used in modern console games. In [3, 4], the methods and challenges of designing accessible games are analyzed from the perspective of the game itself and the user, which also gives the inspiration for the choice of the scope of this research. The scope, or user profile is essential for the whole design method in this research, not only in video games, this research also collect user profile from table games, in [5] the user profile and the way of typical methodologies, limitations are reported; respectively, an efficient accessibility game design will be one of this article's guidance, "The Last of US: Part II" is a uniformed and detailed example in-game field, in [6], the author demonstrates the importance between accessibility and game by providing Active Game Accessibility (AGA) development framework and game accessibility guideline. Although the content of game accessibility above cannot be copied in this paper, the framework they used will be a guide for building an integrated accessibility environment.

To be able to demonstrate the scientific validity of the proposed solution, this paper uses Chinese disabled data [2, 7] and consumer data of different shopping stages produced through the Taobao dataset [8] to be able to analyze the feasibility of the solution mentioned in this paper, this paper introduces two models based on the basic understanding of web accessibility [9, 10, 11], PEQUAL, a comprehensive website based on multiple analysis methods evaluation models, and Web Content Accessibility Guidelines (WCAG) 2.0 is a benchmark to guide web accessibility analysis and design. To visualize the website analysis by WCAG 2.0, tools for website review can be used. Also, an experiment about conversion rate and time of e-commerce websites and some literature reviews about the environment of the e-commerce website for people with disabilities are used for data comparison and discussion [12, 13]. In the models and data above, the detailed data of the users with a disability is not able to be calculated or predicted; this paper will treat the materials above as benchmarks, WCAG 2.0 will be the benchmark of detail UI design while PEQUAL and data from Alibaba open-sourced dataset will be the benchmark while testing.

Apart from WCAG 2.0, there is more technical, biological, or psychological research result that gives guidance to the design and analysis part of this article: The accessibility analysis in Australia e-Commerce website based on WCAG 2.0 [1] and the standard Munsell Color System, which can be the application for helping people with color blindness [14, 15]. The use of the standard Munsell Color System can be more accurate if "Gamut Mask" is also engaged in a website color analysis [16]. Pointing and Clicking difficulties can cause problems shopping online; the behaviors from and assessment for people with clicking challenges [17] can affect the design methods. Using an AI-based voice assistant can also be a solution except for the result above. A study about interaction quality or voice assistant system (VAS) [18, 19] can guide the voice recognition technology in the proposed solution. Both Munsell Color System and voice assistant system are widely used in the field of design and voice recognition, but can't find application in the field of e-commerce websites; this paper will use both of them to build two core functions about colorblind support and voice support in the whole system.

Due to the scope of target users, web accessibility design can be scattered, frameworks for improving accessibility design service [20] and the example for web design from e-government website [21] can give the inspiration to the final united and classified design methods. The external insights above in the both applications proved the feasibility of the solution provided by this paper, also gives the guidance for system testing, but this paper does not share the same group of users, the objective of users are different while using, so while testing and designing, this paper will consider both the successful application and user characteristics.

III. Scope and Purpose

A. Scope

The proposed solution and the analysis are mainly aimed at the classified groups in Table I [7]. At the same time, considering the existence of a particular group of sellers, changes in the design of online shopping systems could change the experience of the seller group; this change will not be considered in the designing part.

B. Purpose

By analyzing Web Content Accessibility Guidelines (WCAG) 2.0, some global e-commerce platforms, and some specific users of these platforms (see "III scope" for details of specific user groups), this article will suggest several solutions to build a more user-friendly online shopping environment for these particular groups. The solutions include 1) a new system design scheme based on user itinerary analysis of different websites; 2) a new interaction design scheme based on the roles of specific user groups.

TABLE I. DIFFERENT TYPES OF DISCUSSION AND THEIR CORRESPONDING SPECIFIC MANIFESTATIONS

The type of disability	the specific manifestation
Visual impairment.	Color blindness; maximum visual acuity in both eyes is less than 0.1; visual field is incomplete.
Hearing impairment.	The structure and function of the auditory system are severely impaired, the average hearing loss of the better ears is between 81 and 90(dB HL), and the comprehension and communication are severely limited.
Dyskinesia.	Cannot use the mouse to make fine movements; using the keyboard input is more complicated.
Comprehension barrier.	Unable to understand long sentences, dyslexia, low comprehension

IV. METHODOLOGY

A. *Analysis*

To make the proposed design method more convincible, the analysis of the using process and user profiles are needed. By analyzing the user journey, comparing the actions and time between different users, the needs from the particular group will appear. Based on WCAG 2.0, the unreasonable design of some certain e-commerce websites can also be found. In total, the analysis will provide the basic logic and reference for design.

1) Analysis of mainstream e-commerce websites: The duration of each step, including the interaction of every stakeholder in the whole user journey, is showed in Fig. 2. Almost every platform from the research, Taobao, JD, Amazon, and eBay, has shared the same process. Those platforms will use different sales strategies or recommendation strategies in different status, but the process itself won't be influenced.

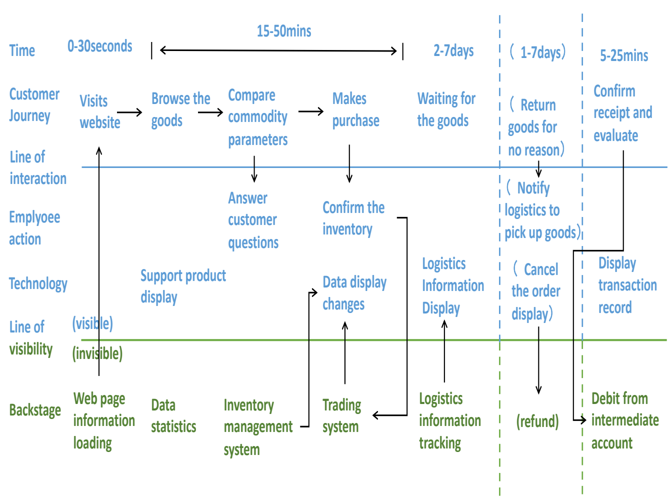

Fig. 2. The Service System of Mainstream e-Commerce Websites in the Market.

Meanwhile, Pinduoduo's service system, as an APP-only platform, is somewhat different from them. When paying for this link, customers can spend less waiting for another customer who purchases goods simultaneously. The general flow of the service system is shown in Fig. 3.

Based on the user journey above, user interface change may change the conversion rate for each status and average spending time on different pages. However, a recommendation system and other sales strategies could also affect the conversion rate. Testing and contrasting the average spending time in different shopping statuses could be more accurate and precise.

2) User analysis

a) User Reaction Time Based on Simulation: The reaction time data should not be affected by subject choices; simply calculating data from user behavior datasets from different e-commerce platforms can hardly ignore the error. A simulation experiment was designed to fix this problem.

This experiment chooses 15 different users who do not have problems using those e-commerce websites by giving them other shopping purposes (for example, user A is supposed to buy powdered milk) to decrease the influence of recommendation and memory. At the same time, this experiment gives users the use of barriers to simulate the target users. The change of CSS filter scale in the source code of an e-commerce website can affect the sight from different kinds of color-blind; the slightly shaking from the mouse to simulate the shaking from hands can be realized by C++ [5]. The experiment result is shown below; all the experiment was based on Taobao China website.

Based on the result in 4.1.1, the test was divided into four parts to simulate: (1) view the homepage and choose classification the user needs, to decrease the influence of personal preference, the classification was randomly chosen in one routine of the test; (2) choose the specific item in the classification page; (3) read the introduction page of items; (4) make payment.

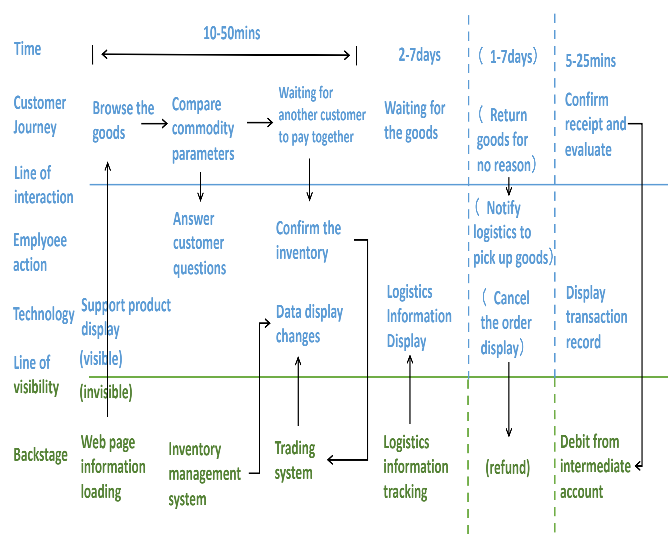

Fig. 3. Pinduoduo's Service System.

TABLE II. SIMULATION RESULT FOR 3 EXPERIMENTAL GROUP

	View homepage /s	determine the specific item/s	read the specification of an item/s	Payment time/s
All color Blind	50.54	16.93	293.93	28.67
presbyopia	56.71	18.94	310.43	33.00
Movement Disorders	42.33	24.57	269.96	36.65
Normal (control Group)	38.10	14.36	261.97	20.05

To ensure the data is accurate and precise, the variation (CV) coefficient was calculated for all the average data in Table II. All the CVs are under 15%, and the first 2 steps have higher CVs while CV in steps 3 and 4 are lower; the errors may come from different familiarities to the Taobao website.

To put four processes into side-to-side comparison, the time of reading the specification takes most of the whole process, which means the information from the item is more important to users. The assistant reading and understanding in this part will be more critical. Viewing the homepage and finding classification takes more time to compare with finding specific items; this result could lead to the question about the main navigation bar; too many sorts may distract the user's attention, or the color and font influence users' judgment.

Fig. 4 is the visualization of Table II. Using the chart to determine the gap of all kinds of simulations, the move disorders group spends more time determining the specific item and making payment. These two parts typically need more interaction, like clicking and typing. Meanwhile, viewing and reading parts are harder for group presbyopia, meaning that the text in those two-part is hard for people to read. Overall, the other 3 groups' average time is higher than standard data; a solution used in the whole process is needed.

b) Portrait the User According to the User's Behavior: The reaction data present the user behavior objectively while the user interview reflects the subjective feelings from the users, which could also be necessary. At present, 10 users were intensely interviewed, including their shopping habits, online shopping routine, and problems they've met were asked. Among these users, some hardly use the online platform for shopping and users who frequently use these apps as well as the linked industry apps; in this section, the target users will be further broken down, and the results of the interviews of these target users are shown in Table III.

The result of user analysis will affect the focus direction of the final solution; for example, the colorblind user takes more time viewing, and using process about "viewing" in these websites may need more colorblind-aimed assistance. In the opposite way, if the solution provided from this paper can decrease the particular using time, the solution can be treated as an ideal solution to the research question this paper proposed.

3) Web design analysis: With the increase in Internet users, the importance of owning a website has increased to manage the business and promote products in all its forms. Every company or business community, whether small or large, has a website that talks about it and its services and products. There must be many features for the design and content of the website to represent a tool to attract the most extensive audience base and attract many new visitors and retain existing visitors. The analysis above is based on users; this section will focus more on web design analysis. Based on WCAG, the color used for a website have strict rules, if the rules are not followed, users can take more time to recognize the message, take the main navigation and search bar from Taobao as an example (Fig. 5), by using a color review tool, the result of color using is showed on Fig. 6, Fig. 7 and Fig. 8.

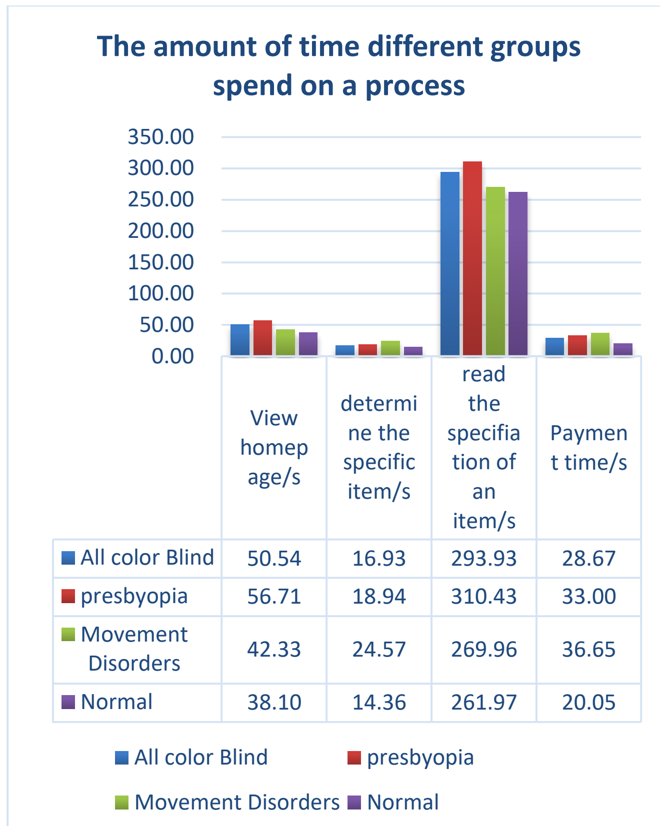

Fig. 4. The Amount of time different Groups Spend on a Process.

TABLE III. INVESTIGATION RESULT

User Type Specification	**User Characteristics**	**User Feedback through e-Commerce website now**
Visual impairment including color blindness, incomplete of visual field	familiar with e-Commerce website but have visual obstacle when using them	Too much information on the main page, hard to recognized different icons belongs to different sub-system
Elder without online shopping experience	familiar with offline shopping, not willing to learn how to shopping online	Too complicated to learn, too much information to understand
Elder with online shopping experience	familiar with all the digital platform for e-commerce, with high user viscosity, but easy be treated	Not familiar with all the discounting policy, cannot be focus sometimes, easy to get tired

Fig. 5. Main Navigation and Search Bar of Taobao (Taobao Homepage).

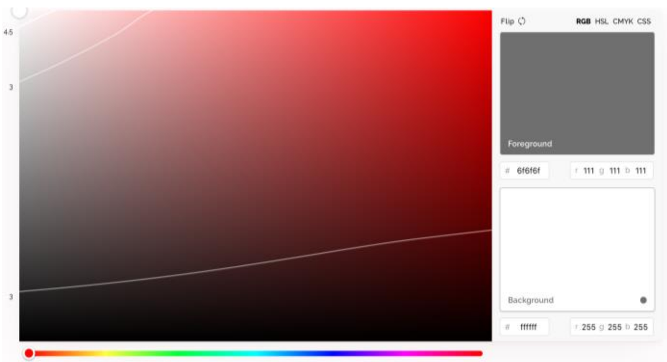

Fig. 6. Color Review of Main Navigation Bar While Not Clicking (ColorReview).

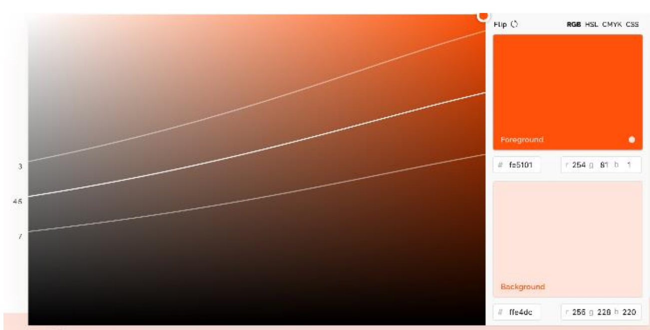

Fig. 7. Color Review of Main Navigation Bar While Clicking (ColorReview).

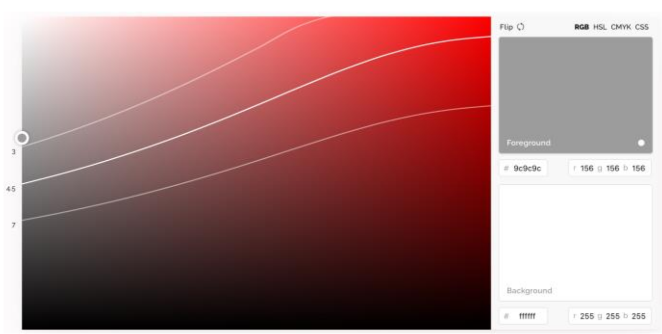

Fig. 8. Color Review of Main Searching Bar (ColorReview).

Three lines on the color review, "3", "4.5", "7", means three standards for AA and AAA in WCAG 2.0, the index of the circle in the graph the higher, the better. In the result of the color review, only the background-text color contrast ratio of the main navigation bar while not clicking fulfilled the WCAG 2.0 AA standard.

Meanwhile, in the main navigation bar, products are classified in 15 blocks, which can be complex for users to organize and remember.

The analysis of the web page, compare with WCAG 2.0 and other benchmarks, can provide the guideline about UI design for the final solution; since the benchmarks, this paper choose are widely used in other fields, including other websites, the result of web design analysis should be convincible and helpful to build a better UI for e-commerce accessibility.

4) Accessibility design: All design methods will be based on analysis and combined with the user profile in the scope. Design methods are divided into two parts according to the problems that need to be solved.

1) problems that need to be solved as soon as the user enters the page; and 2) problems that may need to be solved as the user uses the site.

The solution before using: 1) Visual aids, adjustable font and icon size for the main interface, enhanced contrast for image display, weaker background, highlighting text and product subjects; these adjustments are specified in WCAG 2.0 [10], i.e., text cannot be adjusted, the font needs to be 14-18 px; repeated scrolling of text needs to be in width 320 and height of 256 CSS pixels in the window. Contrast ratios of at least 4.5:1 for large text and up to at least 7:1 for other text. To prevent light epilepsy, interactive animations should preferably not be displayed on the home page, nor should any web content contain any flashing more than 3 times/second.

2) Motion/cognitive aids increase the feedback area, and to address the needs of Parkinson's patients, the delay of the web interaction will be longer, with the highest delay of 3s [10]. The user can control the length of the delay, and the size of the interaction module will be more significant.

The solution while using: 1) Colorblind, color-blind mode, anything related to the discriminability of the web page can be adjusted by the color-blind/color-blind mode, based on the Munsell Color System [4], which is shown in Fig. 9. All colors are represented by hue, luminance, and chroma. The hue is divided into red (R), red-yellow (YR), yellow (Y), yellow-green (GY), green (G), green-blue (BG), blue (B), blue-violet (PB), violet (P), and purple-red (RP); luminance is expressed from white to black from N0-N10; chroma is used to indicate the purity of the hue, and the upper limit of standard colors is about 10. The color-blindness mode mentioned in this paper will be designed for all types of color-blindness using quantitative experiments, which will first determine the lightness as N5 and the chroma as 5, then let users sort the hues, the system interface will have different color matching according to the sorting results (because there is red-green and blue-green color-blindness, the color-blindness mode will be designed for all types of color-blindness). After determining the hues, the adjustment of lightness and chroma will be made according to similar methods to ensure that the needs of all similar users are met.

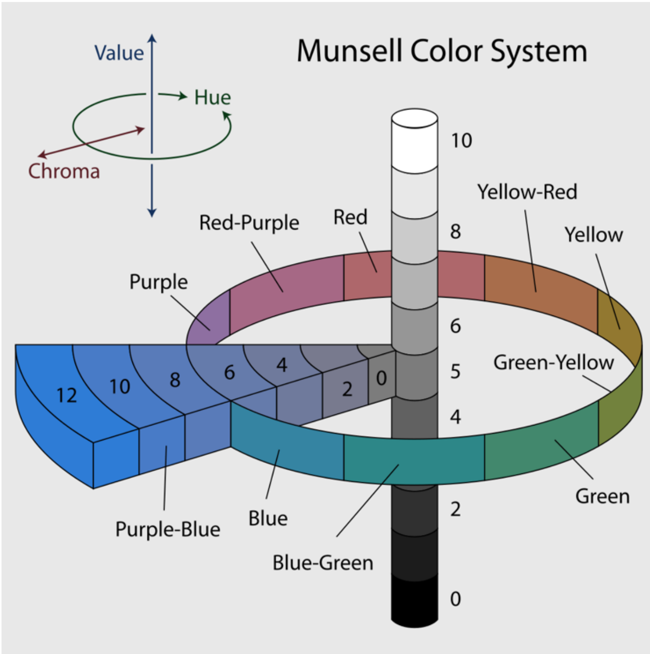

Fig. 9. Munsell Color System [10].

2) Cognitive assistance, this point also applies to users other than visually impaired users; when opening the assistance mode, you need to remove all irrelevant icons, reduce the length of advertising images by 50%, increase the font size to 18px and bold, in the mobile terminal, vibration and touch need to be corresponding adjusted, for example, increase the vibration feedback at each stage of shopping, such as adding a shopping cart, For instance, adding vibration feedback at each step of the shopping process, such as adding a shopping cart for a short vibration, and two long vibrations for payment. Long press on an interactive video can appear auxiliary subtitles, long-press on an extended language can play a voice to assist reading. This mode can also be open as a full voice assistant; users can use voice instead of clicking in the whole process.

The design part suggests separate parts of the e-commerce web accessibility design based on the needs from the analysis part. Also, based on the analysis part, these design methods will be used in the different user journeys to ensure the system's logic and make the system integrated and easy to use; the final solution will be concluded in Section V.

V. Proposed Solution

This section will specifically describe how the above design is implemented in the actual website, taking Taobao as an example; first, for the main page and all the pages that require reading, the contrast rate should at least be 4.5:1, font size need to be larger than 16px, the critical text need to be bold; all the thrilling video cannot be played, the descriptive text should be more precise, especially in the specific item description; The classification in the main navigation bar is suggested to be decreased. Those are a minimum requirement, based on the essential condition, the analysis result, and inspiration from game accessibility; two more things are needed for the system:

1) Calibration of the whole system, at the beginning of the entire process of using, a calibration for accessibility is needed; this article suggests putting the complete calibration in the login page for the influence to normal users won't be strong. Based on the design and analysis above, the calibration process needs to contain:

- Color Sensitivity test, the process will be similar to the method based on Munsell color system in 4.2.
- Font adjustment, adjust the font size, bold or not by giving the user an article.
- Web layout adjustment using block model and click adjustment, by giving a simulated website based on the e-commerce website which is made by different blocks, users can adjust the size of blocks, the system will change the size of pictures in the real website, after finalizing the block, users are required to click some of the buttons, by testing the accuracy of clicking, the system can get the force range and necessary delay.
- Whether to start voice input, if the voice input is open, the voice assistant can be opened, and users can use voice for payment and clicking.

2) Adjustment while using, similar to the settings in the game, users' requirements will change through the using process. The adjustment needs to contain the following functions:

Font: Options: 16px to 20 px, bold or not, all RGB adjust the size of font, color of subtitle and test	**Color:** Options: Blue-green color blindness; Red-green color blindness; Total color blindness adjust the color based on setup template, or do the test again	**Voice:** Options: open or close open or close voice assistant, including voice input and audio cues
Click: Options: small, middle, large; 1-3 seconds to change the button, including the size and delay, the initial delay is 0; size is small	**Hints:** Option: open or close open the hints will highlight all the important information, decrease the unnecessary pictures	**Process Assistant:** Options: open or close; based on the cognitive assistance in 4.2, the information for the products will be concentrated, the voice assistant will work for the whole process.

The adjustment can be a floating window on one side of the website; users can click to open the settings, choosing one of the functions to adjust.

VI. Discussion

Because all the proposed solutions are based on the analysis and authoritative data and models, it is considered as convincible, especially for the part of simulation experiment is useful, if it combines the calculating result based on Alibaba user behavior dataset and Learning optimal tree models under beam search [8], for example, the conversion rate from "adding to cart" to "buy" is 72.9%, these data about the percentage of conversion can also be influenced by time, shopping time and conversion rate are supposed to have some relationship, there's also an experiment support this idea. However, the rate of convincible is still in the theoretical part, in some of the application [20], it is found that users with disabilities are used to ask help while they have using difficulties [13], that makes the promotion and testing of the whole system harder. Also, since the design method may not be suitable for all of the websites (different companies have different design principles), it is better to make the design method of the system like a guideline as WCAG 2.0, which may be more friendly to all the companies.

VII. Challenges and Limitations

While taking care of particular groups, this paper also considers the impact of changing the system on e-commerce companies and tries to make some accessibility design with the most negligible effect on the system itself. The solution above does not need a lot of budget or some significant changes to the original system, so it is available to use.

The difficulty of this study is to find the proper users for testing. Second, because the accessibility design is scattered and fragmented, more requirements will be needed by increasing the user number, so it is necessary to develop more functions based on the coming conditions. The final test of the system is hard to simulate, especially for calibration; the alpha-beta test needs to take a lot of time due to this situation.

Another challenge this system faced is the possible conflict between accessibility and promotion; if the access mode is used, the promotion activities by the e-commerce company will be unavoidable decreased, except for recommender system, moderated promotion or advertisement can improve the profit as well as the user experience, thus, a better way of promotion or a better UI including advertisement is needed, to make the system easy to use and assure the profit of the company at the same time would increase the confidence level of this system.

The provided system can now only work for the buyers, but not the businessmen who also have this kind of situation; if a system for business people is also developed, other stakeholders with the same problems may also struggle because of disabilities, that is because the proposed system is only in the application layer, accessibility design can be used in multiple platforms, multiple occupations, and multiple devices; so, the whole solution can be raised to the system layer.

VIII. Conclusion

To solve the problems for users with disabilities while using e-commerce website, this paper based on the game accessibility design and other related application, analysis the user behavior and user journey and designed an integrated and flexible system for the whole process of online shopping, including UI design and special support (colorblind testing and voice assistant). The proposed system design is convincible by comparing with data and benchmarks, it still needs improvement in many ways like promotion, in the future, the application layer accessibility design may be placed by system layer accessibility, this proposed system is hoped to make some contribution to the narrow sense of accessibility design in the field of e-commerce.

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Research on the Relationship between Exploratory Behavior and Consumer Values using Eye Tracking Gaze Data

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***Abstract*—In recent years, the popularity of e-commerce has witnessed a significant uptick. Physical apparel stores need to implement measures that focus on the behavioral experience of shopping at physical stores, a trait that e-commerce lacks. The purpose of this paper is to clarify the relationship between customer values and product search behavior and proposed product placement and customer service methods based on their values. We used questionnaire data on the values of customer purchasing to perform factor analysis and cluster analysis. Moreover, we extracted the product search behavior using eye-tracking gaze data from an apparel physical store. The results showed that product search behavior differed based on three types: trend cluster, self-esteem cluster, and conservative cluster. Finally, we proposed product placement in a store considering the features of these clusters.**

***Keywords*—Consumer values; eye tracking; factor analysis; cluster analysis**

I. Introduction

In recent years, the popularity of e-commerce has witnessed a significant uptick. According to a market study on e-commerce [1], the e-commerce rate for clothing and apparel was 12.96%. This rate was higher than the average electronic commerce conversion rate of 6.76% for all industries. As for the change in the use of physical apparel stores over the past three years [2], 32.2% of the respondents indicated that the number of items that have "decreased a lot" or "decreased a little". From this result, we found that the opportunity to use physical apparel stores decreased. Furthermore, in the same survey, the top three answers for “characteristics of physical stores actually visited” were “trying it in direct contact,” “buying it on the spot and take it home,” and “shopping with family and friends.” Therefore, it is necessary to develop marketing strategies that take advantage of the strength of physical apparel stores. Physical apparel stores need to implement measures that focus on the behavioral experience of shopping at physical stores, a trait that e-commerce lacks. One of the major differences between physical stores and e-commerce is the ability to experience the store environment and to receive customer service [3]. Improving the services and merchandising offered by physical stores can help improve the store image, and in addition, such improvement increases customer satisfaction [4,5]. In order to improve these services and merchandising, it is necessary to clarify the customer service required by customers. Therefore, we focused on the relationship between customer values and customer purchasing behavior. Since the use of eye tracking is effective in visualizing purchasing behavior [6], we conducted an experiment using eye tracking devices in this study. In the first part of the paper, we discussed related research on the relationship between values and purchasing behavior, and related research on the eye tracking case used in the analysis, and finally, we proposed product placement and customer service methods.

II. Literature Review

To improve sales in youth clothing purchases, Matsumoto et al. [7] stressed the importance of improving the environment inside the store and customer service skills of its employees. Hence, the two key takeaways from this study are store environment and customer service. In their study on the hotel industry, Ando et al. [8] indicated that customer service requirements differ depending on the values of customers. Therefore, capturing customer value should serve as a guideline for customer service and product placement in physical stores so as to fully use the advantages of behavioral experience of a physical store. In the area of eye tracking research, the role of gaze information on purchasing has been studied [9]. By using eye tracking, it is possible to visualize what information is important in purchasing. Zuschke, N. et al. [10] about research on eye tracking suggested that in-store marketing activities would encourage product selection. Bialkova S. et al. [11] conducted an experiment in a laboratory and a supermarket and suggested that placement is an important determinant in a storefront environment. Thus, the information obtained from the experiment in physical stores can be useful. There are many studies that use eye tracking for fashion, for example, understanding the purchasing patterns of mobile consumers [12], understanding the information about online shopping [13], and evaluating the design of products [14]. However, in the research on shopping using eye tracking, there are few examples of viewpoint observation experiments in physical stores of fashion brands. Therefore, in this study, we conducted viewpoint observation experiments in physical store and analyzed them using the eye-tracking data obtained.

III. Purpose of this Study

The purpose of this study is to classify the relationship between customer value and product search behavior. Specifically, we used questionnaire data on the values of customer purchasing to perform cluster analysis. Next, we extracted the product search behavior using eye-tracking gaze data from an apparel physical store. Based on these results, we compared and analyzed clusters and propose customer service and product placement methods based on customer values.

IV. Data

A. Questionnaire Data of Customer Value

We used questionnaire data about the life index conducted in 2015. The target items included 23 items about fashion and values for purchasing. Questions about fashion include those about the quality and value of clothes, the way people choose clothes, and how they appear in those clothes. Questions about purchasing include questions about how people shop, how they choose, and how they think about products. The rating was based on a five-level scale (1: Not applicable at all, 5: Exactly applicable). This study included a total of 4946 people: 4930 women in their 20s and 30s, who were the subjects of questionnaire data analysis and 16 other who cooperated in the viewpoint observation experiment.

B. Viewpoint Observation Data at Apparel Stores

We conducted a consumer behavior experiment using a gaze-measuring device at a roadside apparel store on October 15 and 17, 2019 in Tokyo, Japan. Considering that the main target of the target brand in the store was for women in their 20s and 30s and fashion clothing involvement was significantly affected by a consumer's gender and age [15], we conducted this experiment with 10 women in the 20s under the same conditions. The store deals chiefly in bags, clothes, accessories, wristwatches, and shoes. Women's products could be found at the 1F and 2F floors. Fig. 1 and Fig. 2 show the layout of the store. Table I and Table II list the product shelves on each floor. We used "Tobii Pro Glasses 2" [16] to record eye tracking during the experiment. This device can move freely while wearing and records what the subjects are looking at. Moreover, when we analyzed the recording data, we used "Tobii Pro Lab" [17] to process the recording data. In order to unify the experimental conditions, the subjects wearing the eye tracking device looked around all floors in the store for 20 min. Before the experiment, we asked the subjects to answer a questionnaire about their preferences and characteristics. As the after-questionnaire once the experiment was over, we asked impressive items and items that they wanted. The study by Saijo et al. [18] was used as reference to create the experimental procedure and questionnaires.

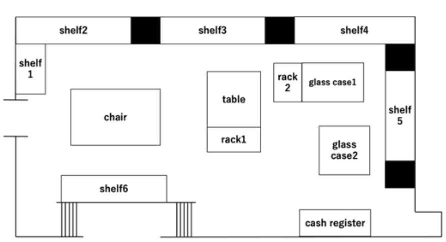

Fig. 1. Layout at 1F.

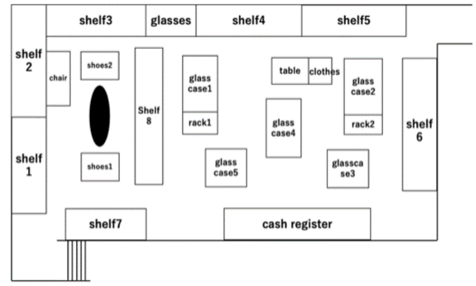

Fig. 2. Layout at 2F.

TABLE I. The Product Shelves List at 1F

The Product Shelves	Kinds of Products
Shelf 1	Collaboration Products
Shelf 2	New Arrivals, Handbags, Tote Bags, Backpacks
Shelf 3	Handbags, Tote Bags
Shelf 4	Pass Cases, Wallets, Handbags, Shoulder Bags
Shelf 5	Shoulder Bags, Boots, Handbags, Backpack, Body Bags
Shelf 6	Shoulder Bags, Backpacks, Tote Bags, Sneakers, for Men
Chair	Handbags, Sneakers
Table	T-shirts, Handbags, Wallets
Glass Shelf 1	Wallets, Pass Cases, iPhone Cases, Key Cases, Pouches, Key Rings
Glass Shelf 2	Wristwatch
Rack 1	Small Shoulder Bags
Rack 2	Large Shoulder Bags

TABLE II. The Product Shelves List at 2F

The Product Shelves	Kinds of Products
Shelf 1	Sneakers, Boots
Shelf 2	Small Handbags, Sneakers
Shelf 3	Sandals, Boots, Handbag
Shelf 4	Small Handbags, Tote Bags, iPhone Cases
Shelf 5	Small Handbags, Shoulder Bags, Wallets
Shelf 6	Medium Handbags, Shoulder Bags, Sneakers, Backpacks
Shelf 7	Handbag, Shoulder Bags, Mini Wallets, Boots
Shelf 8	Boots, Pumps
Glasses	Sunglasses
Table	Handbags, Backpacks, Body Bags, Sneakers
Clothes	T-shirts, Jackets
Glass Case 1	Pass Cases, Key Cases, Wallets, iPhone Cases, Pouches, Key Rings, Handbags
Glass Case 2	Wallets, Key Cases
Glass Case 3	Wristwatches
Glass Case 4	Accessories
Glass Case 5	Wristwatches
Rack 1	Small Shoulder Bags
Rack 2	Large Shoulder Bags
Shoes 1	Sneakers
Shoes 2	Sandals, Pumps

V. Analysis of the Relationship between Customer Values and Product Search Behavior

This section describes the analysis results and the considerations regarding the values. The analysis flow is shown in Fig. 3. First, we conducted a factor analysis using questionnaire data to derive the basic values of fashion and purchasing. We categorize consumer values by referring to the flow of analysis in the study by Ando et al. [8]. In addition, we referred to the papers by Kimura et al. [19] and Matsuoka et al. [20] that used factor analysis and cluster analysis in the analysis of values. To classify customers into groups based on their values, we conducted a cluster analysis based on the results of the factor analysis [21]. Next, we conducted three kinds of analyses to extract, compare, and analyze consumer search behavior for each cluster. Finally, we propose customer service and product placement methods based on customer values.

A. *Derivation and Typification of Basic Values Related to Fashion and Purchasing*

Factor analysis is a multivariate analysis method used for finding common factors hidden in multivariate data. We executed the minimum residue method and promax rotation for 23 items of questionnaire data on living indicators. From the results of the screen plot, we identified six factors. Since we deleted five items for which the factor loading was not sufficient, we ended up with 18 items, and the explanation rate for variance was 44%. Table III lists the resulting factor loadings. We named each factor based on the characteristics of the questionnaire items.

The show-off factor was named after the response to wanting to attract attention in fashion. The quality importance factor was named after the response that emphasized quality. The innovator factor was named based on the importance placed on the new products. The faddism factor was named based on responses about how people around them saw them. The commitment factor was named after thinking about and buying things. The intuition factor was named based on the responses to impulse buying. Next, to classify customers based on their values, we conducted a hierarchical cluster analysis. Hierarchical cluster analysis is a statistical analysis method that collects similar items from a large group and divides them into groups. Based on the results of the factor analysis of the basic values of fashion and purchasing, we calculated the factor score using the regression method. To examine the tendency of respondents to the factor scores of six factors, we performed a cluster analysis using the Ward method and classified questionnaire respondents into three clusters based on the results of the dendrogram. We used the Euclidean distance as the distance between the data. The results are presented in Table IV and Fig. 4.

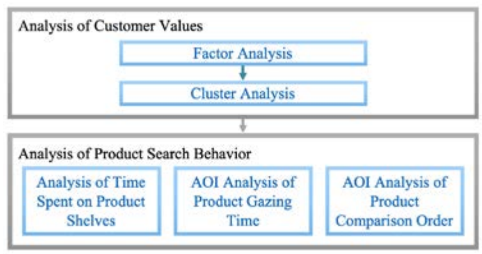

Fig. 3. The Analysis Flow in this Paper.

TABLE III. Questionnaire Items on Values Selected by Factor Loadings

Questionnaire Items	**Factor Loadings**					
	Show-off	**Quality-oriented**	**Innovator**	**Faddism**	**Commitment**	**Intuitive**
I want to attract attention in fashion.	0.982	-0.034	0.055	-0.111	-0.083	-0.111
I want to choose clothes that I can use for as long as possible.	-0.084	0.714	-0.084	0.062	-0.017	0.018
I want to choose good quality clothes. I want to handle them carefully.	0.304	0.679	0.023	-0.091	-0.056	-0.002
I want to use good things carefully for as long as possible.	-0.132	0.607	0.032	-0.007	0.148	0.046
I actually buy new products. I'm a person who tries various things.	-0.008	-0.023	0.715	-0.091	0.028	0.126
I check the information of new products diligently.	0.075	-0.024	0.688	0	0.074	-0.071
I'm curious about how I feel from the surroundings.	0	0.009	-0.168	0.686	0.043	-0.056
I often want what people around me have.	-0.041	-0.014	0.253	0.509	-0.136	0.109
I only want to put what I like around me.	-0.085	0.109	-0.018	0.036	0.548	0.088
I think that individuality appears in what kind of shopping you do.	0.031	-0.012	-0.045	0.112	0.53	0.091
Shopping often doesn't compromise until I find what I really want.	-0.059	0.076	0.144	-0.045	0.529	-0.263
I often buy what I like intuitively on impulse.	-0.117	0.043	0.034	-0.067	0.045	0.802
I'm in trouble because what I want comes out one after another.	0.062	0.009	0.099	0.264	0.017	0.295
I want to have something different from the people around me as much as possible.	0.255	-0.096	0.019	-0.147	0.433	0.167
I like to have branded things.	0.405	0.063	0.236	-0.018	-0.056	0.02
I want to improve my fashion sense.	0.45	0.144	-0.064	0.283	0.046	-0.037
I want to be seen from the surroundings.	0.458	-0.119	-0.077	0.263	0.159	-0.059
I often shop by referring to the best-selling rankings.	-0.048	-0.016	0.286	0.429	-0.003	-0.093

TABLE IV. THE AVERAGE VALUE OF FACTOR SCORE ON THREE CLUSTERS

Cluster Name	Factor Score					
	Show-off	Quality-oriented	Innovator	Faddism	Commitment	Intuitive
Trend	1.02	0.36	0.11	-0.38	-0.46	-0.20
Self-respect	-1.02	0.05	-0.03	0.18	0.34	0.50
Conservative	0.18	-0.43	-0.09	0.18	0.07	-0.40

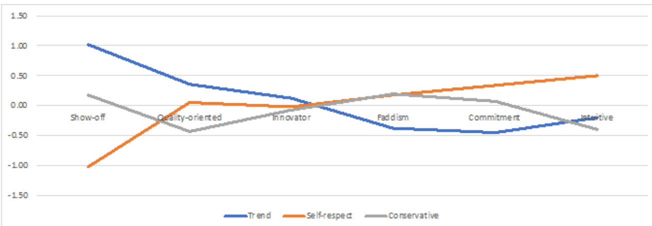

Fig. 4. Visualization of the Average Value of Factor Score on Three Clusters.

The trend cluster included 1583 people, the self-respecting cluster had 1842 people, and the conservative cluster had 1521 people. Among the 10 subjects who participated in the experiment under the same conditions, two were in the trend cluster, five were in the self-respect cluster, and three were in the conservative cluster. Furthermore, we categorized consumers into three clusters based on their values. The values of the show-off factors, quality-oriented factors, and innovator factors were high. As a result, they tend to grab new products and information and are more sensitive to fashion trends. For self-respect clusters, the values of the faddism, commitment, and intuition factors are high. It is a cluster that values one's core and sensibility while being sensitive to one's own way of seeing and the trends around oneself. Conservative clusters have only a high Faddism factor and less noticeable results for other factors. It is a cluster that likes basics and does not adventure.

B. Analysis of Time Spent on Product Shelves

To classify the differences between the clusters, we aggregated the time spent on product shelves. The results for 1F are shown in Fig. 5, and the results for 2F are shown in Fig. 6. The detailed results for each cluster are discussed in Section VA.

C. Product Evaluation on Product Shelves using AOI Analysis

Next, we conducted an area of interest (AOI) analysis to see whether there were differences in the products they were looking at on the shelves among the value clusters. The AOI analysis is a function of the eye-tracking device software Tobii Pro Lab [17], which enables us to measure the number of gazes and gazing time of the area of interest by specifying the area of interest from the recorded data [22]. Total visit duration on an information sign was found as the strongest predictor of product choice by Bridget K. Behe et al. [23]. In this study, we extracted total visit duration of the item area for three product shelves on the first and second floors. We set two conditions as selection criteria for the three shelves: the products could not be seen from multiple directions, and there were no clusters with zero time spent on the shelves. We chose Shelf 2, Shelf 3, and Shelf 4 on the first floor, and Shelf 1, Shelf 4, and Shelf 5 on the second floor. Here, we present the results of Shelf 4 on the first floor (Fig. 7 and Table V) and Shelf 4 on the second floor (Fig. 8 and Table VI), in particular, where differences among clusters are characteristically found.

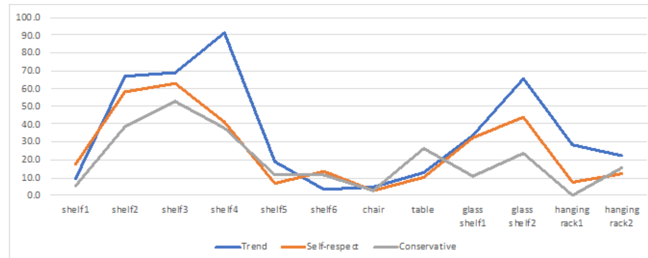

Fig. 5. Graph of Time Spent on the Product Shelves at 1F.

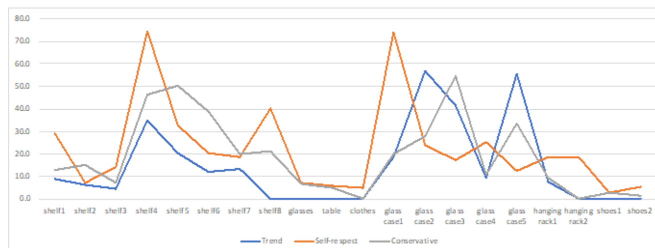

Fig. 6. Graph of Time Spent on the Product Shelves at 2F.

Fig. 7. Picture of Shelf 4 on the First Floor.

Fig. 8. Picture of Shelf 4 on the Second Floor.

TABLE V. AOI ANALYSIS RESULT OF SHELF 4 ON THE FIRST FLOOR

Cluster	**1_1**	**1_2**	**1_3**	**1_4**	**2_1**	**2_2**	**2_3**	**2_4**	**3_1**	**3_2**
Trend	0.00	0.26	0.55	0.42	2.06	1.02	1.32	2.41	0.70	1.38
Self-respect	0.00	0.26	0.31	0.12	0.26	0.83	0.19	0.28	1.05	1.36
Conservative	0.00	0.33	0.04	0.26	0.63	0.46	0.10	0.08	1.20	1.51
Cluster	**3_3**	**3_4**	**4_1**	**4_2**	**4_3**	**4_4**	**5_1**	**5_2**	**5_3**	**5_4**
Trend	1.94	3.41	1.45	2.04	3.91	4.05	1.19	2.18	2.80	5.20
Self-respect	1.18	1.57	1.04	0.77	0.98	0.64	1.52	0.31	0.36	0.17
Conservative	0.44	0.29	0.24	0.05	0.47	0.07	0.17	0.82	0.26	0.45

TABLE VI. AOI ANALYSIS RESULT OF SHELF 4 ON THE SECOND FLOOR

Cluster	**1_left**	**1_right**	**2_center**	**2_left**	**2_right**
Trend	0.00	1.90	0.75	0.57	1.23
Self-respect	0.15	1.85	1.41	0.82	2.91
Conservative	0.10	1.58	0.93	0.61	1.13
Cluster	**3_left**	**3_right**	**4_center**	**4_left**	**4_right**
Trend	2.81	3.56	0.44	0.60	0.64
Self-respect	2.04	4.67	1.82	0.70	0.29
Conservative	2.67	3.99	1.31	0.24	0.84

TABLE VII. THE TENDENCY OF THE ORDER OF GAZE AMONG THE CLUSTERS

Subject No.	**Cluster Affiliation**	**Action**	**Comparison Tendency**
1	Trend	The first time, she looked at all the products, and then compared them with the black products; the second time, she focused on the camera bag on the fourth shelf.	Compare shapes → Compare colors
2	Trend	She focused on the red and beige products.	Compare shapes
3	Self-respect	The first time, she compared shapes (black, red, and white); the second time, she compared the chain bag and then the camera bag.	Compare shapes → Compare colors
4	Self-respect	She compared vertically and compared colors by shape	Compare colors
5	Self-respect	She compared the same color to each other	Compare shapes
6	Self-respect	She barely looked at the beige product in the first row; she focused on the camera bags in the second and fourth rows	Compare colors
7	Self-respect	After she compared the camera bags in the second and fourth rows, she touched the products in 4_4 and compared the chain bag	Compare colors
8	Conservative	After looking at them, she touched 2_3 and 3_2	Don't look at anything but the product she was interested in
9	Conservative	She looked mainly at the camera bags on the second and fourth rows, then looked at the chain shoulder a little	Compare colors
10	Conservative	After looking at the whole, she compared the black products, and then touched 3_4 for the second time, comparing the color of the camera bag	Compare shapes → Compare colors

The AOI analysis includes a function to visualize the order in which the viewpoints were moved in each area for a single product shelf. We compared the tendency of the order of gaze among the clusters. In this study, we analyzed Shelf 5 on the second floor, where shoulder bags were lined up in the same shape as the products. The results are listed in Table VII. The results showed that there were four patterns of product comparison methods: those who compared shapes with colors, those who compared shapes, those who compared colors, and those who gazed at only the most visible product for a long time. However, there were no differences among clusters.

VI. DISCUSSION OF ANALYSIS RESULTS AND PROPOSALS FOR PRODUCT PLACEMENT AND CUSTOMER SERVICE METHODS BASED ON EXPERIMENTS

This section discusses the results of the analysis described in section IV. Specifically, this study clarifies the relationship between consumers' sense of value and searching behavior. In addition, based on the results of the analysis and consideration, we propose a shelf arrangement in the store.

A. Discussion of the Relationship between Consumer Values and Product Search Behavior

Based on the results of Section IVB, we found that the product shelves that are easily gazed at tend to be gazed at in all clusters. Shelves 2, 3, and 4 on the first floor and Shelf 4 on the second floor are the product showcases where people spend the most time. Therefore, the shelves with multiple types of bags facing the front left-hand wall from the entrance are in the golden zone, where they are easily gazed at and searched. In contrast, we found that the time spent in the product shelves of collaboration products, men’s products, clothes, and collection products that emphasize the attractiveness of the brand are short. From the results in Section IVC, the overall tendency of the results is that flashy products are more likely to attract attention in all clusters. Therefore, when placing products, combining eye-catching products with products that attract attention can effectively increase the chances of customers discovering the products. In addition, the height of the product shelves that are most likely to be gazed at correspond to the products on the second to third shelves from the top. This result was similar to the study of Piotr Chynał et al. [24]. This shows that the location of the product shelf and its position on the shelf are also important for optimal product placement. Table VIII shows the summary of product search behavior.

In the trend cluster, the results of Section IVB show that the time spent in the product shelves with small bags, small items, and wrist watches was longer. The results of Shelf 4 on the first floor show that it has the largest bias in terms of the time spent on the products, indicating that it is the cluster that tends to compare the products it likes. As for bags, there is a tendency to prefer small handbags and shoulder bags to large ones. This may reflect the recent trend for smaller bags rather than larger bags. In the self-respect cluster, the time spent on shelves with flashy bags and small items was long. Based on the results of Shelf 1 and Shelf 4 on the second floor, the self-respect cluster was the only cluster that often looked at shoes. In addition, the results of Shelf 4 on the second floor showed that they tended to look at products with patterns and flashy colors more often than other clusters. This may have been influenced by the concept of the fashion brand in this experiment as a self-respect cluster. As for the conservative cluster, the shelf-gazing time was shorter than that of the other clusters, indicating that they tended to look at the shelves from a bird’s-eye view. The conservative cluster tended to pay more attention to the eye-catching products. The conservative cluster tended to look at products from a bird’s-eye view and did not pay attention to any product for a long time, resulting in the least bias. Therefore, the conservative cluster reflected the tendency to prefer basic products and not to try new or flashy products.

B. Suggestion for Product Placement and Customer Service Methods based on Experiments

The display of trendy and recommended products on the product shelves of the first floor is necessary to present the brand concept. However, no one in any of the clusters gazed at the display for a long time to search for products. Therefore, it is effective to place the product shelves near the entrance to present the concept, and to arrange the products around the shelves so that they can be easily compared. Table IX shows the summary of suggestion based on experiments.

TABLE VIII. SUMMARY OF PRODUCT SEARCH BEHAVIOR

Cluster Name	Characteristics of product shelves with long staying time	Characteristics of products that are likely to attract attention
Trend	There're small bags, small items, and wrist watches.	Size: small
Self-respect	There're flashy bags and small items.	Colors: flashy, bright, patterned cloth Category: shoes
Conservative	No bias compared to other clusters.	They don't gaze at any product for a long time.

TABLE IX. SUMMARY OF SUGGESTION BASED ON THE EXPERIMENTS

Cluster Name	Product Placement Method	Customer Service Method
Trend	Placing products of multiple colors and shapes in the same place for easy comparison	Present products in a way that makes them easy to compare
Self-respect	Placement of recommended products in combination with eye-catching products	To introduce trends and popular products.
Conservative	To place together products that are easy to coordinate, flashy products that catch the eye, and products that are recommended	To combine products and present them as coordinated

Since the trend cluster tends to compare products they like, it is effective to place products of multiple colors side by side so that they can be easily compared and place trend products on the second to third height from the top where they can be easily seen. In terms of customer service, since customers often tend to compare products, it is considered effective to talk to them and recommend products to them when they have narrowed down their search. In addition, it is good to compare and recommend products with the same tendency as the products customers like. Self-esteem clusters tend to pay attention to products with flashy colors and patterns that are likely to catch their eyes, and thus, it is effective to present trends and recommendations in an easy-to-understand manner. Therefore, it would be beneficial to place recommended products in combination with eye-catching products and place products on the shelves in a conspicuous manner. In terms of customer service, it is important to inform customers of the current trend and popular products. The conservative cluster often looks at products from a bird's-eye view more than any other cluster, and thus, it would be beneficial to arrange products in such a way as to increase opportunities to encounter products, for example, by not placing similar shapes and colors of products together, so that customers can see a full range of products. Products that are easy to match as coordinates or flashy products that easily catch the eye and recommended products should be placed together. In terms of customer service, it is also important to recommend combinations of products and to encourage customers to compare products when they stop by so that they can find their favorite color or shape.

VII. Conclusion and Future Work

We aimed to clarify the relationship between customer values and product search behavior and proposed product placement and customer service methods based on their values. The results showed that product search behavior differed based on three types: trend cluster, self-esteem cluster, and conservative cluster. Trend clusters tended to observe and compare products more closely and had greater variability in product gazing time. Self-esteem clusters tended to look at products with patterns and flashy colors more often than other clusters. The conservative cluster tended to look at products from a bird's-eye view and did not pay attention to any product for a long time, resulting in the least bias. In addition, we proposed product placement in a store considering the features of these clusters.

In future work, we need to understand what kind of values the customers who use the store tend to have. Therefore, we think that it is necessary to speculate using purchase data, analyze the difference in the initial movement of product search for each sense of value, and analyze the reaction to customer service in future work.

Acknowledgment

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Lip Detection and Tracking with Geometric Constraints under Uneven Illumination and Shadows

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***Abstract*—In the modern era, recent advancement in computer vision has led to emergent attention in lip reading. Indeed, lip-reading is used to understand speech without hearing it, and the process is mentioned as a lip-reading system. To construct an automatic lip-reading system, locating the lip and defining the lip region is essential, especially under different lighting conditions, significantly impacting the robustness of the lip-reading system. Unluckily, in previous studies, lip localization under illumination and shadow consideration has not been well solved. In this paper, we extant a local region-based approach towards the lip-reading system. It consists of four significant parts, firstly detecting/localizing the human face, mouth and lip region of interest in the first video frame. Secondly, apply pre-processing to overwhelmed the inference triggered by illumination effects, shadow and teeth appearance, thirdly create contour line using sixteen key points with geometric constraint and stored the coordinates of these constraints. Finally, track the coordinates of sixteen points in the following frames. The proposed method adapts to the lip movement and is robust in contrast to the appearance of teeth, shadows, and low contrast environment. Extensive experiments show encouraging results and the proposed method's effectiveness compared to the existing methods.**

***Keywords*—Lip detection; lip tracking; illumination equalization; shadow filtering; 16 points lip model**

I. Introduction

The continuous progress of technology brings to an irreversible change of paradigms of interaction between humans and machines. Traditional ways of human-computer interaction using keyboards, mice, and display monitors are being replaced by more natural modes, e.g. speech, touch, and gesture. New PCs, tablets and smartphones are moving increasingly toward a direction that will bring in a short time to have interaction paradigms so advanced that they will be completely transparent to users. In recent years, to automate the process of voice communication with which they interact between themselves persons. Lip movement and reading are used to recognize speech from a speaker without hearing. It is a procedure that especially gets to grips by people having hearing problems. In 1976, audio-visual illusion became recognize as the McGurk effect [1], which shows that visual cues information combined into the listener's mind automatically and unintentionally. The listener perceived the syllable, which is dependent on the visual information and strength of audio from the speaker.

In the past, there are two main techniques, edge and region-based, proposed for lip segmentation and extraction by using spatial information (edge and colour) to track lip movement. Hue and edge information are used to attain mouth localization and segmentation [2]. Initially, visual features extraction is obtained in greyscale images [3, 4]. The vertical center of the lip region is used to initiate by compelling the sum of each row in the mouth region and finding the minimum value of the row. The corners of the lips are found by setting the threshold, and horizontal edges are representing by four parabolas of both lips (lower and upper lips edges). They use the linear filter to find the edges. Another method is applied to the greyscale image [4], which is very close to the above method, but this approach tracks the unnecessary features in the mouth region such as nostril and pupils. The statistical colour model was used to locate the face by normalizing the skin colour [5]. Outliers are used to find the position of features points in all frames of the image sequence, and sometimes these positions are not the best. The performance of these techniques failed to produce an accurate result in cases when a speaker has beard and teeth presence. The beards have high edges in both directions (vertical and horizontal) mentioned in [6]. Therefore, the edge-finding method is not helpful for persons having bears. The HSI (hue, saturation and intensity) colour space extracts mouth pixels and sorts out the illumination from colours[7]. Hue values redefine the lip pixels. Different colour spaces [8, 9] and approaches have been used for visual feature extraction, e.g. optic flow analysis [10]. However, these methods failed with data sets of more than one few words and were computational intensive [11].

The active contour model (ACM) detects the lip boundary's edge [12]. Unluckily, this model often converges to the wrong result when the lip edges are indistinct, or the lip is very similar to the skin region. The region-based approaches mostly use the regional statistic characteristics to comprehend lip tracking. Distinctive examples include deformable template (DT) [13, 14], region-based ACM [15], active shape model (ASM) [16,17], and active appearance model (AAM) [18]. A regional cost function is used by DT to divider a lip image into the lip and non-lip regions via a parametric template, which represents the lip shape properly. Therefore, globally statistical characteristics have been used in mostly region-based approaches.

Consequently, their performance may decrease due to the appearance of teeth, tongue or black hole. The localized active contour model (LACM) [19] have better results. However, LACM depends on the proper correlative parameters.

Moreover, the colour information is not considered [19], which is very important to improve extraction performance, particularly when the images have shadows [20, 15].

This paper presented an approach to lip detection and tracking with two main phases: (i) lip contour extraction for the first frame and followed by (ii) lip tracking in the following lip frames. In the first phase, we created the dataset from a different speaker, i.e. Male/ female, different age groups by uttering English alphabets and numeric numbers in different light conditions, defining the mouth ROI, and applying pre-processing methods. Then, we utilized a 16-point lip model [21] with geometric constraints to achieve lip contour extraction. We repeat the same procedure for the lip ROI image and compute the lip tracking in the second phase. The proposed approach is adaptive to lip movement and robust against the appearance of the illumination effects, teeth and shadow. Experimental results have shown promising results.

II. METHODOLOGY

Previously, videos dataset created by using compression, controlled light environment, constant background for processing [22] led to noisy pixels in frame images, slow performance and caused false feature detection. We created the video datasets in different lighting conditions, gender (male/female) and different age groups. Some male persons had a moustache as well. A small application was developed for recording the video files by using Visual C++ and OpenCV [23]. These videos were recorded in the Computer Vision Lab of the University of Pavia at different times, using a Logitech HDR webcam with the highest possible resolution supported by the camera. Each speaker had to record the video by uttering different alphabet letters and numbers.

A. Face and Mouth Detection

Face and Mouth detection have a vital role in lip localization. Firstly, it is necessary to detect the speaker's face in all video frames and crop the speaker face for the mouth area. Numerous approaches have been already developed and categorized as: i) colour based [24], ii) template-based [25], and iii) feature-based [26,27]. Face detection methods based on local features and machine learning-based binary classification methods[28] have been widely used in various face recognition studies because of their real-time capability, high accuracy, and availability in the OpenCV, but the mouth area detection was not detected accurately. Only face detection results were accurate. To overcome this problem, we used the face image and split it into two parts horizontally. The upper part has the eyes, forehead and a small part of the nose. The lower part has the mouth on which we applied the mouth cascade classifier, obtaining precise results as shown in Fig. 1.

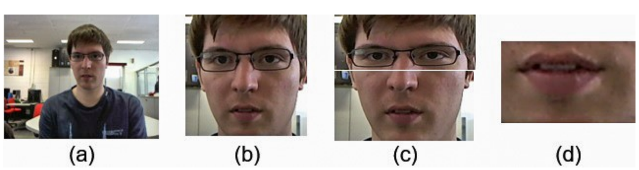

Fig. 1. Face and Mouth ROI Detection a)Frame Detection b) Face Detection c) Face Image Splitting d) Mouth Detection.

III. PRE-PROCESSING

A. Illumination Equalization

Mouth ROIs are extracted from videos acquired, where sometimes lightning is very strong and irregular. This irregularity is the cause of various disorders that can lead to malfunctions of the lip-reading application and make it challenging to identify the crucial points and construct the 16 points lip model. Different methods have been proposed for image enhancement [30], Histogram equalization, and lighting [20]. The method [29] works exclusively on the luminance value of the individual pixel. Although, It has few flaws, such as the effects of irregular lighting are attenuated only along with the single direction vertical and fixed scaling size of image 71 x 44 and mask size 3x3. We decided to improve the model [30], making it more robust with respect to light, multiple directions horizontal and vertical, working no more than on the single pixels and on local regions within the image. The extended algorithm can adapt to the multiple directions of the lighting, as shown in Fig. 2 [20].

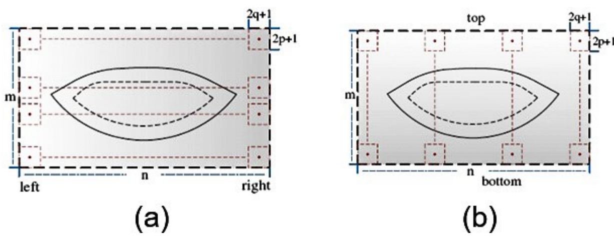

Fig. 2. a) Horizontal Direction b) Vertical Direction [20].

The colour lip image size m × n provided to the function's input is initially converted in HSV colour space, let L (i,j) is the L' (i,j) represents the luminance of each pixel respectively before and after the operation of equalization. To simplify the process, assume that the non-uniform illumination is instead linear along the direction of its application. As mentioned earlier, the innovation brought to a method implemented in this elaborate consists of manipulating the individual pixel's luminance value but work on a local region of size (2p + 1) × (2q + 1). Each pixel of the original image assumes the value obtained from calculating the average of the luminance values of all the pixels included in the mask that flows throughout the image along the two main directions identified. The luminance value of the pixels (Horizontal and Vertical directions) was calculated using the application formulated in formulas 1, 2.

$$\boldsymbol{L'}(i,j) = \begin{cases} L(i,j) + \frac{(n-2j+1)*(r(p)-l(p))}{2(n-1)}, & i \in [1,p] \\ L(i,j) + \frac{(n-2j+1)*(r(m-p)-l(m-p))}{2(n-1)}, & i \in [p, m-p] \\ L(i,j) + \frac{(n-2j+1)*(r(i)-l(i))}{2(n-1)}, & i \in [m-p, m] \end{cases} \quad (1)$$

$$\boldsymbol{L'(i,j)} = \begin{cases} L(i,j) + \frac{(m-2i+1)*(b(q)-t(q))}{2(m-1)}, & i \in [1,q] \\ L(i,j) + \frac{(m-2i+1)*(b(j)-t(j))}{2(m-1))}, & i \in [q, n-q] \\ L(i,j) + \frac{(m-2i+1)*(b(n-q)-t(n-q))}{2(m-1)}, & i \in [n-q, n] \end{cases} \quad (2)$$

Where l_i and r_i denote the average intensity of respectively left and right edges of the local region of size (2p + 1) × (2q + 1), to the i_{th} row of the mask. Similarly, t_j and b_j denote the average intensity of the upper and lower edges of the local region at the j_{th} column of the mask, as shown in Fig. 7.

B. *Teeth Filtering*

During the experiment, it was observed that illumination equalization is not enough to improve the system. Still, some other factors are to be considered, e.g. the teeth, black hole, and tongue region that can be visible in processed images. In the past, the researchers reported that without considering these factors cannot have a robust result for lip tracking [31]. The proposed teeth filtering method removes the teeth appearing in the mouth (ROI) in all frames. The presence of teeth in the image frame is observed when the mouth status is open. It was possible to construct a filter dependently on thresholds, which correctly identifies the range of colour that characterizes the range of the tooth region in the Mouth (ROI). The implemented function inputs the illumination equalized image and then convert it into two different colour spaces *CIELAB* and *CIELUV*. *RGB* colour space has characteristics that are not suitable for defining the thresholds based on which it filters the region of teeth. The teeth region is characterized by the lowest components a∗ and u∗ present in the image. The two threshold values have been set for the two chromatic components of interest. L_{au} has demonstrated that to achieve a satisfactory result, the teeth thresholds t_a and t_u should be set according to the formulas (3) [41].

$$t_a = \min\left(\mu_a - \sigma_a, 9\right] \text{ Otherwise if } \left(\mu_a - \sigma_a\right) < 9$$

$$t_u = \min\left(t_u - t_u, 29\right] \text{ Otherwise if } \left(\mu_u - \sigma_u\right) < 29 \qquad (3)$$

Where μ_a, σ_a, μ_u and σ_u are, respectively, the mean and standard deviation of the chromatic components to a∗ and u∗. According to this approach, all the pixels that relate to the teeth may identify pixels that correspond to the teeth i.e. $a^* < t_a$ or $u^* < t_u$ or L^* 35% or L^* 95% in the chromatic components reference as white, normalized to restrict their range of the standard deviation in 2 around the mean value. Each pixel characterizing the teeth is masked by resetting the colour value of all the chromatic components of the specific colour space identified. It cannot influence the future operations of search from the position of the mouth. If there are no teeth, a presence mask will not apply, and if teeth appear, the mask will remove the teeth pixels by changing the teeth pixels value to 0.

C. *Shadow Filtering*

A mean filter is used to reduce noise caused by shadows in the images described [32]. Again, these disturbances are because of different lighting conditions, e.g. sourcing light angles and shades beneath the lower lips. The rate of recognition of a lip-reading system is based on the accuracy of the lip position. Unfortunately, up to now, there are no algorithms not effectively solved the problem of locating the lips in uneven lighting conditions. Illumination equalized images used to reduce the interference brought by shadow. For the implementation of the shadow detection method, we used these steps: i) Convert the illumination equalized image into grayscale, ii) Considering the image as a matrix in which the rows are characterized by the index "i" and columns from the index j. iii) Calculate the accumulation of the grey level value for each column of the image and obtain a column index corresponding to the mean value of the accumulation curve as the boundary of shadow. It is used to divide the grayscale image into two sub-images, left Isl and right Isr, to enhance the contrast between lips and the surrounding skin region (4).

$$I_e = \frac{255(I - I_{min})}{(I_{max} - I_{min})} \qquad (4)$$

$$\delta_i = dist(I^{(i+1)}), \quad (I^{(i)}) \qquad (5)$$

Where, I_{min} is the minimum grey-level value in the image, and I_{max} is the maximum value. Euclidean distance δ_i is determined by calculating the distance between (I^i) and (I^{i+1}). If δ_{i+1} is greater or equal to δi then the process will stop, and (Ii) will be marked as the final image. The convolution process ends when the Euclidean distance decreases by less than two units between two subsequent iterations. We determined if each sub-image and the whole image and output image Isl are extracted by subtracting the initial and final images in the proposed function. The shadow detection ends by making a new image by merging two images, left Isl and right Isr. The middle line obtained between Isl and Isr by curve, having information about boundaries of lips and skin region and the minimum value of the row position, is considered the corner points of the lips. Finally, a convoluted image is extracted, as shown in Fig. 3.

Fig. 3. Smoothing the Contrast (a) Greyscale Image (b) Left Image (I_{sl}) Convoluted, (c) Right Image (I_{sr}) Convoluted (d) Output Image.

IV. Lip Detection

In this step, we have to mark the exact position of the lips. An elliptic shape function [36] was applied to detect the lip boundary. This method gives good results when the mouth status is closed, but when the variation in lips, some marginal parts of this elliptic region may be far away from the lip boundary. Lip corner dots are successfully implemented by using intensity variation and colour cues in [19, 33], as shown in Fig. 4(a). We proposed the extraction method for geometric positions by labelling the left corner, right corner, upper corner and lower corner as points L_a, L_b, V_a and V_b as shown in Fig. 4(b).

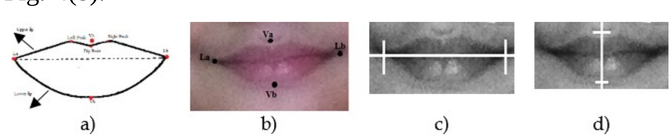

Fig. 4. a) Standard Lip Model b), Geometric Points of Interests, c) Crucial Points Horizontal d) Crucial Points Vertical.

A. *Crucial Points (L_a, L_b, V_a, V_b)*

To identify the horizontal crucial points; we extracted the left point L_a and right point L_b. Points are located on the median axis of the image and stored in a vector. The values of curve G have peaks of high frequency due to noise. This noise must be clear to ensure the precise extraction process of crucial points. A low-pass filter applied of Butterworth through mask size 3 3 pixels that run through everything the curve G to reduce the noise. The vector filtered result, called Gf proceed with the search of the crucial points. Accumulate the grey-level value for each column of the image and obtain correspondence column index to the mean value of the accumulation curve as the boundary of shadow. The boundary shadow value, median axis and sub-images Isl and Isr already have from the shadow filtering phase. This whole curve G consists of both sub-images divided by boundary shadows. The curve representing the vector G should be monotonically decreasing to quickly identify the crucial point left as that point occurs the maximum value of the gradient, considered absolute value. This value corresponds to the boundary between the mouth region and skin. The positions of mouth corners correspond to the steep slopes of the curve, as shown in Fig. 4(c,d). The method for searching for the left crucial point consists of several steps. Firstly, obtain the first minimum' m’ by scanning Gf from left to right. To work in the best possible conditions, make the monotonic curve and save this new curve in a vector support Gm using formula (6).

$$G_m^{(i)} = \begin{cases} G_f^{(i)} & (G_f^{(i)} \geq G_f^{(i+1)}) \\ G_f^{(i+1)} & (G_f^{(i)} < G_f^{(i+1)}) \end{cases} \tag{6}$$

Once curve is extracted, carry out all the values of the vector Gm in the correct range of processing for grayscale images, therefore ensuring the pixels fall in the range between 0 and 255 by using the following formula (7).

$$G_m^{(i)} = \frac{255(G_m - G_m^{(min)})}{G_m^{(max)} - G_m^{(min)}} \tag{7}$$

Gm is used to search the left crucial point, but unfortunately, there is no maximum rate, although the curve is monotonic. To overcome this problem, calculate the average pixels values of the vector Gm as shown in equations (8) and (9) are utilized to adjust the image's contrast on the horizontal median axis.

$$C^{avg} = \frac{\sum_{i=1}^{k} C'}{K} \tag{8}$$

$$I_{out} = \begin{cases} 255 & 1.5C^{avg} < I_{in} < 1 \\ \\ \frac{500}{C^{avg}}, & 0 < I_{in} < 1.5\, C^{avg} \end{cases} \tag{9}$$

Where I_{out} and I_{in} are the output and input grey level values, the I_{out} is obtained by adjusting the curve and a binary image; those pixels values are 0 or 255. The local minimum point is identified in the position for the first time, where the pixel changes from 255 to 0. Curve C was obtained after the adjustment of contrast and crucial points (L_a , (L_b). The vertical points made a start from the results as described in horizontal crucial points. Based on the position of the horizontal crucial points, calculate the mouth’s centre point, and its column index is marked as vertical midline of the mouth, in which two crucial points, vertical Va and Vb are situated. The pixels values that lie on the vertical axis are divided into two groups and stored on a vector to be processed. We built two more vectors, respectively called B1 and B2, containing only the pixels with a value equal to the maximum, corresponding to the value “1”, and the pixels with a value equal to the minimum conform to the value “0”. In addition, two binary vectors B_1' and B_2' are obtained by applying logical operation that provides outbound B1 and B2 as described in equation (10).

$$B_1' = B_1\, XOR\, (B_1 \ll 1) \quad B_2' = B_2\, XOR\, (B_2 \ll 1) \tag{10}$$

The operator $\ll$ indicates the logical operation of shift one position to the left. At this stage, crucial points Va and Vb are identified. These points where the first occurrence of the value of $'1'$ inside of the vector $B1'$ while Vb fits in the position in which, the last occurrence of the value $'1'$ inside of the $B2'$.

B. Draw Ellipse

The next step is to find an ellipse that encloses the mouth region. In some cases, the ellipse position is incorrect because the bottom point V_a is not proper. To overwhelm this problem, draw two half-ellipses, one for the upper lip and one for the lower lip. This trick shows more precise and realistic results. This method identifies the coordinates xI, yI of the horizontal crucial points Lax, Lbx and Lay, Lby and vertical crucial points Vax, Vbx and Vay and Vby by using geometrical formulas for drawing an ellipse. The centre of the mouth is calculated with equations (11).

$$x_c = \frac{1}{2}\,(La_x + Lb_x) \quad y_c = \frac{1}{2}\,(La_y + Lb_y) \tag{11}$$

The inclination of the half-ellipses for the horizontal plane is calculated with equation (12).

$$\theta = \arctan\left(\frac{La_x + Lb_x}{La_y + Lb_y}\right) \tag{12}$$

The semi-major axis a common to both the half- ellipses, calculated as in formula (13). The semi-ellipse of the upper lip and the lower lip's semi-ellipse is shownin equation (14).

$$a = \frac{1}{2}\left((Lb_x - La_x)^2 + (Lb_y - La_y)^2\right)^{1/2} \tag{13}$$

$$b_{up} = \frac{1}{2}\left((Va_x - x_c)^2 + (Va_y - y_c)^2\right)^{1/2}$$

$$b_{low} = \frac{1}{2}\left((Vb_x - x_c)^2 + (Vb_y - y_c)^2\right)^{1/2} \tag{14}$$

xc,yc be the centre of mouth coordinates and origin of the combined semi-ellipse, calculated as formula (15). Where ‘a’ is the semi-major axes, bup and blow are the upper and lower semi-minor axes. θ is the inclined angle, defined at the counter-clockwise direction.

$$\frac{x_{up}^2}{a^2} + \frac{y_{up}^2}{b_{up}^2} = 1 \qquad \frac{x_{low}^2}{a^2} + \frac{y_{low}^2}{b_{low}^2} = 1 \tag{15}$$

C. Lip Modeling

The Lip model was used to determine the accurate boundary line and geometric points around the lips. We have already extracted four points left, right, top and bottom in the previous section. Previously, lip modelling was performed without pre-processing, which may cause incorrect tracking results, i.e. four key points model with two parabolas for the lip contour used in [34] and six key points with cubic curves connected to describe the lip shape used in [35]. First, sixteen point geometrical deformable models are used in [21]. It is challenging for the modelling of the lips in non-ideal conditions. A model-based approach was proposed for lip contour extraction from colour images to overcome this problem. A region-based cost function is employed to formulate the entire lip contour extraction as a region partition problem instead of the conventional edge detection problem. The proposed algorithm is more robust with low colour contrast, and the final extraction result is less sensitive to the initial model parameters than the edge-based. Curve C0 is used as a curve of evolution for the initial model development of the model. The proposed algorithm is the extension of the 16 points lip model as described in [21]. These geometric constraints showed the lip boundary, and we will store the location of these points and then track the lip movement. The 16 lip boundary points labelled P0 to P15 in anti-clockwise and parameter set by equation (16).

$$\lambda_p = \{x_{pi}, y_{pi}\} \quad where\ i = 0, \ldots .15 \tag{16}$$

These points are divided into three groups as the lower lip (P_0,P_7,P_{15}), upper right lip (P_7- P_{11}) and upper left lip (P_{11}- P_{15}). A normalization process was used to translate the lip corner points P_7 and P_{15} to lie on the horizontal x-axis and point P_{11} on the vertical y-axis. The centre origin of lips is set to be the midpoint between the two lip corners, P7 and P15. After normalization of the mouth ROI, the next step is constructing the 16 points lip-model lips. Lip modelling is split into two parts model i) initialization and ii) thresholding.

- Lip Model Initialization

Elliptical regions extract the lip contours [36] but give the approximate surrounded area of lips, not precise lip. Therefore, a minimum-bounding ellipse as the initial evolving curve is used to find the extract of the lip contours. Model initialization is the starting point of the construction of the lip model. Using the ellipse's geometric parameters is already identified, and the ellipse showed the accuracy of locating the mouth region in the video frames. Therefore, some adjustment operations are required to simplifying the process of initialization of the model. We used three functions, probability map, cost function formulation and draw graph to obtain more accurate model construction.

The teeth pixels with a∗ < ta or u∗ < tu for colour component ‘a’ and ‘u’, also white pixels of L∗ ≤35 marked and discarded in lip initialization process and assign probability values on marked pixels. Teeth pixels are always inside the mouth and assigned high values of probability. It helps the model to separate the upper and lower lip. The surrounding teeth are considered lip pixels with low luminance values and equal probability values 0.5 are assigned. A low pass filter and cost function are applied to smooth the probability map to optimise the process and determine the optimum partition when the cost function in equation (17) is maximized [21].

$$max \left\{ C(\lambda_p) = \prod_{(x,y)\epsilon\, R_l(\lambda_p)} prob_l(x,y) \ * \ \prod_{(x,y)\epsilon\, R_{nl}(\lambda_p)} prob_{nl}(x,y) \right\} \tag{17}$$

Where λp is the 16 point model parameters, probl (x, y) and probnl (x, y) are the probabilities of lip pixels and non-lip pixels at location (x, y), Rl and Rnl are the enclosed and outside the region by the point model. The lip model fitness evaluated by extension of the cost function. Draw Graph proposed to draw the graph extraction points starting from the parameters of the lips. Draw the rectangle around the mouth, tolerance value calculated based on the image's height, and enlarge a variable value the rectangle within which to seek the edges of lips. The rectangle is determined by the ellipse, which allows the search of the representative point of the intersection with the green ellipse. Calculate the center point of La, Lb and Va, Vb crucial points and mark the points as shown in Fig. 5. The model initialization worked with two single-channel images ’H’ of HSV obtained from the original RGB and Ellipse image. The final mouth ROI image is obtained by subtracting the ellipse H image from the original input H image.

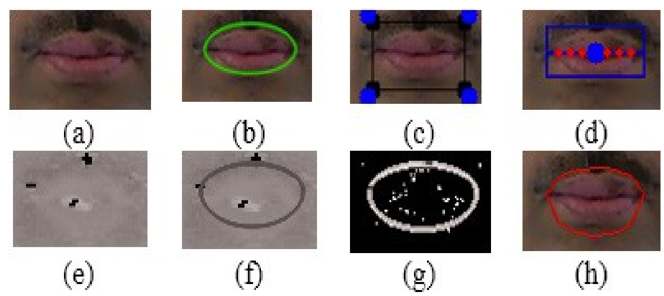

Fig. 5. a) Original Image, b) Ellipse Image, c) Draw Rectangular d) Graph Points, e) ’H’ Channel Image (b), f) ’H’ Channel Image of Ellipse *’RGB’* Image , g) Subtracted Image, h) Final Result.

- Lip Model Thresholding

In this section, we refine the position of the lips points and store the coordinates (x, y) of all points. These coordinates are stored in a file and later will be used in the lip-tracking phase. The channel ‘H’ is used to search the points of the model, and this process is implemented similarly to model initialization. The segmentation was carried out as follows: the red colour of channel H was exploited to find better positions for each point. We looked for neighbour pixels of each point; if there was a significant variation of the red colour (lips to the skin), upgrade the position of the point. The tolerance value for the lower and upper lips have already been calculated. The points P15, P7 have already been found and used in the same position. The position of the remaining 14 points will be upgraded by using means of this procedure. We divided the image into four parts. The lower lip boundary with white points and the upper lip boundary with yellow points are clearly visible. We added the two horizontal corner points P15,P7. Finally, the resulting image has 16 points, as shown in Fig. 6(e,f).

D. Lip Tracking

We have been extracted the 16 points with their positions and coordinates of the first frame. And then tracking algorithm is applied to track the movements of the lips with these points in the subsequent frames. They assumed that frames are extracted from the same video sequence and have almost the same geometric characteristics. It was decided to simplify the extraction phase of the contour of the lips in the remaining frames to considerably overcome the computational algorithm's burden. Pre-processing is carried on all frames. The bulk of the computational algorithm has segmented the image to identify the mouth. Once this process is completed for the first frame, the differences between two consecutive frames are minimal and are limited exclusively, e.g. the lips assume during speech. In this way, it is limited processing on the second frame to a portion of the image significantly smaller, as shown in Fig. 6(e), (f). The construction of the 16 points lip model on the second frame in the sequence is applied exclusively in the image identified. We have coordinates of lips points in the first and second frames. Table I is showing the (x, y) coordinates of two frames. The first frame is the initial frame when the mouth status closes, and the second frame when the speaker said alphabet B, the mouth status is changed and has different coordinates. The upper part of the lips is moved because slight variation is obtained in P5, P4, P6, P15 points, and considerable variation in P9, P13, P14 points.

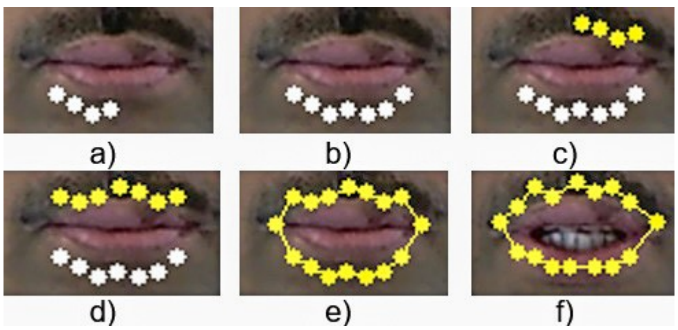

Fig. 6. Drawn Points of the Four Parts of the Image (a)4 Left Lower Points (b) 3 Right Lower Points (c) 4 Right Upper Points (d) 3 Left Upper Points (e) Final Result 1st Frame f) Final Result 2nd Frame.

TABLE I. COORDINATES OF 16 POINTS FIRST AND SECOND FRAME

First Frame			Second Frame		
Point	**X**	**Y**	**Point**	**X**	**Y**
0	21	34	0	18	32
1	28	38	1	25	34
2	35	42	2	32	38
3	42	40	3	39	38
4	50	42	4	49	38
5	57	40	5	56	38
6	64	34	6	63	34
8	64	10	8	63	12
9	57	12	9	56	6
10	50	8	10	49	8
11	43	6	11	42	4
12	35	10	12	32	10
13	28	12	13	25	6
14	21	10	14	18	14
7	72	21	7	74	20
15	14	21	15	11	20

V. RESULTS AND DISCUSSION

All the frames were processed in two sizes 150x150 and 360x360. The results showed that it was possible to extract the contour of the lips precisely in many of the data sets, but some experiments did not go well, where the software did not work correctly (about 5% of cases). The lip tracking procedure is applied to sequences of frames, starting with the first frame to complete the entire sequence. The average processing time for performing lip tracking is about 0.556 seconds to extract the contour of the lips from the first image of the sequence and approximately 0.09 seconds for subsequent frames. Such times include the operations of reading and writing the images used to test the algorithm. It is estimated that the video stream can achieve a frame rate of about 12-15 fps (frames per second) to allow a real-time execution. Face detection in videos was our first step to build the speech recognition system. Secondly, the mouth was detected in the face image, and mouth ROIs were defined for further processing. The accuracy of the classifiers is described in Section II(A), as shown in Table I. To increase the accuracy rate for mouth detection, we improved the mouth cascade and compared it with previous classifier results, as listed in Table II. The proposed method for mouth detection showed more precise results as compared to the earlier methods.

Furthermore, an effective method to reduce the effects of uneven illumination is proposed as more robust to light, multiple directions (horizontal and vertical), and working on both the single pixels and on local regions within the image. Fig. 7 is showing the effectiveness of the proposed illumination equalization method. There are some darker parts on the left or right side, and the same in vertical directions where darker parts are on the top or bottom. The darker part was significantly reduced by applying the proposed method, as shown in Fig. 7(d).

In the previous lip-reading system, teeth masking was not considered, as it was found based on local regions and exploited information on colour inside the mouth. The proposed teeth detection method successfully removes the teeth area in the mouth ROI in all frames and pixels belonging to teeth removed, as shown in Fig. 8(a).

TABLE II. COMPARISON OF MOUTH DETECTION

Facial Features	Positive Hit Rate %	Negative Hit Rate %
Face	90	29
Mouth [29]	67	28
Proposed	86	19

a) Original image b)horizental [20] c) Vertical [20] d) proposed

Fig. 7. Comparison of Illumination Equalization.

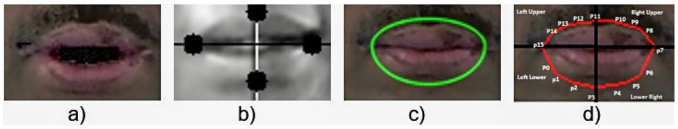

Fig. 8. Proposed Method Results a) Teeth Filtering b)Crucial Points c) Semi Ellipse d) 16 Points Lip Model.

In the past, shadow filtering methods have been proposed for indoor environments and have not been studied for lip localization. Therefore, we proposed a technique for shadow removal as described in the shadow filtering section. After applying the pre-processing steps, a filtered image was obtained where uneven equalization, teeth filtering, and shadows were significantly reduced. In the next step, mark the exact position of lips, which leads to lip detection and tracking. An elliptic shape function is used for lip detection [12]. In this method, lip detection is correctly performed when the mouth is closed; on the other side, some parts of the lip region are discarded during lip movement. Lip corner dots are successfully implemented by using intensity variation and colour cues in [37, 38]. These dots do not fit the exact geometric position of lip structure. Therefore, We proposed a method for extracting the horizontal and vertical positions of median axes of the mouth by labelling the left, right, upper and lower corners as points La, Lb and Va ,Vb. The results of crucial points as shown in Fig. 8(b). Crucial points are needed to draw the ellipse. The upper lip has three corners: left, right, and dip points due to Cupidon’s bow. Fig. 8(c) is showing the result of the proposed combined semi ellipses methods. Different lips models were applied, e.g. four key point models and six key point models [34,35]. We used the 16 points, lip model. The elliptical regions extract the lip contours [12], but they do not give precise lip contours. Therefore, the combined ellipse is used as the initial evolving curve to find lip contours in the proposed method. Some adjustment operations are applied to simplifying initialization by using probability map, cost function formulation and draw a graph to obtain more accurate model construction. A Thresholding function was used to refine the initial evolving curve image better to get a precise position. The lip image is divided into four parts: Left lower P0-P3, Lower right P4-P6, Right upper P8-P10 and Left upper P11-P14 and stores the coordinates of each point, as shown in Fig. 8(d).

Table III described the computation time obtained by the proposed method for the first frame as 0.556 seconds, which is smaller than the methods' results described in [21, 35, 15]. The average computation time of lip tracking for one frame is 0.099 seconds, which is less than the methods' values [21, 35, 15]. The method [21] needs to compute the probability map at every frame. The method [35] requires a bit more pre and post-processing techniques and adjustment processes to fit the lip boundary. However, the average computation time of tracking one lip frame is higher than [38].

The average extraction performance and lip boundary extraction degraded due to low contrast, uneven lighting conditions and irregular shapes in the lip image. The proposed pre-processing methods are applied to the complex appearance of shadows, uneven illumination and teeth. These factors are considered, and the extraction performance of lip boundary extended up to 96%, as shown in Table IV.

TABLE III. COMPARISON OF COMPUTATION TIMES (SECONDS)

Frames	**Barnard et al. [38]**	**Wang et al. [21]**	**Eveno et al. [35]**	**Yiu et al. [15]**	**Proposed**
First	Manual	1.232	0.623	0.695	0.556
Tracking	0.0989	0.133	0.171	0.103	0.099

TABLE IV. COMPARISON OF FEATURES EXTRACTION PERFORMANCE (%)

Data set	Kass et al.[12]	Liew et al. [20]	Leung et al.[39]	Werda et al. [40]	Proposed
	79.50	92.50	89.00	91.00	96
Average	76.7	89.57	83.71	88.57	96

VI. CONCLUSION

An approach to detect and track lip boundaries is presented that highlights the lips and avoids other factors, e.g. false lip pixels and recovers from failures. The proposed algorithm comprised the lip-tracking module from the lip boundary lines, a feature vector of 16 points lip model. Three pre-processing steps, illumination equalization, teeth detection, and shadow removal, aim to investigate edge information and global statistical characteristics. The lip tracking method used 16 points lip model on the lips, stores the coordinates of these points and tracks these coordinates during the utterance by the speaker. Moreover, the proposed method is easy to implement and computationally efficient, capable of locating face and mouth and lips feature points that give a high accuracy rate for lip localization, modelling and tracking accuracy.

Experiments have shown that outliers detecting and better predicting ROIs can reduce the number of frames with locating or tracking failures. This research work brings together new methods, representations, and insights, which are quite generic and may have broader applications in computer vision, image processing, and speech recognition.

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Data Hiding Method with Principal Component Analysis and Image Coordinate Conversion

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***Abstract*—Data hiding method with Principal Component Analysis (PCA) and image coordinate conversion as a preprocessing of wavelet Multi Resolution Analysis (MRA) is proposed. The method introduced in this paper, based on the characteristics of the original multispectral image, allows recovering the secret data. Through experiments, it is found that the proposed method is superior to the conventional data hiding method without any preprocessing. The method introduced in this paper allows only I who knows the characteristics of the original multispectral image to recover the secret data, i.e., when the information of the original image needs to be protected. Moreover, in the introduced method, the information of the secret data is protected by the existence of the eigenvector and the oblique coordinate transformation, that is, the secret data is restored if at least the information of the true original image is not known. The principal component transformation coefficient differs for each original image and is composed of the eigenvectors of the original image.**

***Keywords*—Multi-dimensional wavelet transformation; multi resolution analysis (MRA); image data hiding; secrete image; Daubechies basis function**

I. Introduction

There are social problems such as illegal copying of digital contents such as DVDs and billing for music broadcasting / broadcasting. To solve this, it is necessary to keep content IDs and digital signatures highly confidential. Therefore, a global standard method such as copy prohibition and one-time copy permission is about to be developed. Digital contents of corporate electronic records, customer information, intellectual property, electronic medical records, etc. based on ISO 15489 (record preservation management guidelines) For copyright protection of digital contents (detection of digital signatures and tampering) that must be protected as personal information, and also by inserting a time tag in multimedia such as video, still image, music, etc. and using it to edit In order to efficiently perform charging, or to extract billing information classified by broadcast format, and only those who have obtained permission using a digital signature can share the content. Data Hiding techniques for such Kill manner are used [1].

Data hiding, which is also called information hiding, is a technique for hiding some information in the content. Here, the name of data hiding is used. Data hiding is a watermark (Digital Watermark) technique or steganography (Steganography) [2 - 4]. A technology that makes embedded information important and its existence unknown is called steganography. If the content itself in which confidential information is embedded is important, a digital watermark is used. The original content is called the original content, the data to be hidden such as a signature is called secret data, and the content in which the secret data is embedded is called distribution content. Watermark information embedding technology (watermark technology) has already been studied [5 - 8].

As a method of embedding the secret data in the content, a method of embedding the secret data in the real space of the content [9] and a method of embedding the secret data in the frequency space have been proposed [10],[11]. The latter has a higher ability to conceal the secret data information than the former because the secret data can be embedded in a specific frequency band that is relatively unaffected by the content quality. Therefore, for example, when the content is an image, it is necessary to manipulate the edge part of the original image to embed the secret data [9]. In the latter case, the frequency band of the original content in which the secret data should be embedded must be determined [7], [10].

A data hiding method has also been proposed when the original content is a color image [11], [12]. The secret data embedded in the original content is information such as copyright, and it has high resistance to image processing and removal attacks, and high confidentiality. The method of selecting the coefficient after the original content such as an image is transformed into the orthogonal frequency space and embedding the secret data in the frequency space is often used because it satisfies these requirements. Among them, a method has already been proposed to obtain distribution contents (images) by dividing the image into frequency components by wavelet multiresolution analysis (MRA) [13],[14], replacing any of the divided frequency component images with secret data, and reconstructing (combining).

The conventional method does not necessarily have sufficient confidentiality (it is possible to find it because any of the frequency component images contains confidential data), and the invisible (difficulty of visibility) of the confidential data is insufficient. When the original content is an image, data hiding using a color image has a higher ability to conceal secret data than other methods from the viewpoint of the amount of information in the original image. Therefore, a method of embedding secret data in a certain component (red, blue, or green component) of the original content (image) is generally used [4]. Since the embedding method is used, in this case, the information on the red and the blue components of the original image are not used. Because a certain color component is used in the embedding process.

Data hiding based on wavelet multi-resolution analysis is a method of investigating wavelet frequency components and embedding secret data in components that have a relatively small effect on image quality, but it is widely used. Since confidential data can be located by using this method, a problem remains in confidentiality. To overcome this problem, a method of applying principal component conversion to the original content (image) as a preprocessing of data hiding has also been proposed [15],[16],[17]. Since only I who owns the original content (image) can know the unique value of the original content (image), only I can restore it.

However, this method is not sufficiently confidential because it can estimate the approximate value of the eigenvalue by allowing a certain amount of error using the distribution contents (images) in which secret data is embedded. Pre-processing for cross coordinate transformation has also been proposed [18]. The cross angle of the cross coordinate can be set arbitrarily, and the principal component conversion can be performed based on this angle, which improves confidentiality [19]. A method has also been proposed that improves the visibility and confidentiality of confidential data in distribution images by converting the method [20].

Fundamentals of wavelet analysis and its application to data hiding are described in the books [21],[22],[23]. Method for data hiding based on Legall 5/2 (Cohen-Daubechies-Feauveau (CDF) 5/3) wavelet with data compression and random scanning of secret imagery data is proposed [24]. Improvement of secret image invisibility in circulation image with Dyadic wavelet-based data hiding with run-length coding is also proposed [25]. Meanwhile, noble method for data hiding using Steganography Discrete Wavelet Transformation (DWT) and Cryptography Triple Data Encryption Standard (DES) is proposed and well reported [26].

This paper outlines data hiding methods based on the wavelet multi-resolution analysis and evaluates the effect using images that are frequently used as standard images for data compression.

II. Data Hiding based on Multi-Resolution Analysis

A. Wavelet Multi-Resolution Analysis

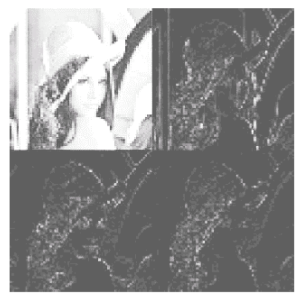
The biorthogonal wavelet decomposition (discrete wavelet transform based on biorthogonal basis function) applies $y = Cn\ x$ by applying the square matrix Cn to the original data (one-dimensional scalar data: $x = (x_1, x_2, .., x_n)$). It can be defined as x, where Cn is a transformation matrix based on a biorthogonal basis function with $CnCn^t = I$. After conversion, y consists of low-frequency component L and high-frequency component H. That is, x is transformed as y = (H1, L1), where the subscripts of H and L are the number of transformations, that is, the number of stages (level by applying Cn to this L1, it is transformed into H2 and L2, and by repeating this n stages, it is transformed into Hn and Ln. This is called decomposition.

The inverse transformation is $Cn^{-1}. = Cn^t$ applying to y. By repeating this inverse transform n times, x is restored. This is called reconstruction. This wavelet transform / inverse transform (decomposition / reconstruction) is repeated Then, the decomposition into wavelet frequency components and the reconstruction of the original data using the decomposed components are called multi-resolution analysis. When this is applied to two-dimensional data, for example, an image, y = (HH1, HL1, LH1, LL1).

Here, HH1 means the high-frequency component in both the vertical and horizontal dimensions, and similarly LL1 means the low-frequency component in both the vertical and horizontal dimensions. This is called the two-dimensional wavelet transform. Each frequency component can be decomposed, and the original image data can be safely restored (reconstruction) by repeating the inverse transformation as in the case of one-dimensional data.

Fig. 1 shows the images obtained by applying the two-dimensional wavelet transform to the [Lenna] in the standard image database (SIDBA), which is often used to evaluate the data compression method, in one and two stages. At this time, Daubechies is used as the biorthogonal basis function. This original image is shown in Fig. 2.

When the DWT is applied to n time series data in one stage, it can be decomposed into n / 2 high frequency components and n / 2 low frequency components. By further subjecting the n / 2 low frequency components to a one-stage DWT, the n / 4 low frequency components and the n / 4 high frequency components can be decomposed.



(a) Level 1

(b) Level 2

Fig. 1. Examples of Images of which 1st and 2nd levels of DWT Applied to Lena of Original Image.

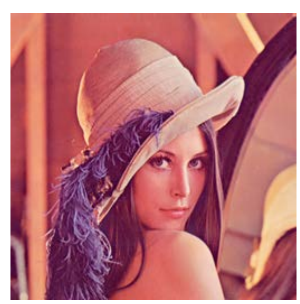


Fig. 2. Original Image of Lenna.

B. Wavelet Multi-Resolution Analysis Based Data Hiding

The secret data embedded in the original content (image) is information such as copyright and signature (including the image), and data hiding requires resistance to image processing and removal attacks, and high confidentiality. The method of selecting the coefficient after transformation to the orthogonal frequency space and embedding the watermark in the frequency space is often used because it satisfies these requirements. Among them, the wavelet multiresolution analysis introduced here (for each frequency component of the image This method is often used to obtain distribution data (images) by dividing them into images, replacing any of the divided frequency component images with secret data or secret data (images, signatures), and reconstructing (synthesizing).

C. Proposed Data Hiding Method

In order for improvement of confidentiality and visibility by eigenvalue expansion, the following data hiding method is proposed. Data hiding based on MRA is insufficient in confidentiality and visibility, and in order to overcome this problem, a method of performing principal component conversion as a preprocessing of data hiding based on MRA has been proposed. Only I who owns the original image can know the eigenvalue and eigenvector of the image, so only I can restore the original image. Therefore, I can claim the copyright of the original content. However, this method is not sufficiently confidential because the approximate value of the eigenvalue can be estimated by allowing a certain amount of error using the distribution image with embedded secret data.

In order to overcome this problem, there is also proposed a pre-processing to perform the oblique coordinate transformation after the principal component transformation, in which the oblique angle of the oblique coordinate can be set arbitrarily, and the principal component transformation can be performed based on this angle. The confidentiality of the content is highly protected under the condition that only the transmitting and receiving parties of the original content can know this angle information. Moreover, the Least Significant Bit (LSB) of the original content is encrypted by encrypting the angle information by a common key method. By inserting it in (the least significant bit in the quantization), the confidentiality can be set even higher. Here, I introduce data hiding based on multi-resolution analysis with principal component transformation and oblique coordinate transformation.

The process flow of this method is shown in Fig. 3. First, the energy of the original image is concentrated by principal component transformation, and the Cartesian coordinates of the transformed principal component image are transformed to oblique coordinates to further increase the energy concentration. Then, the MRA is applied to this, and the distribution image is obtained by reconstructing after embedding secret data in any of the levels and frequency components after decomposition. Since the principal component transformation parameters consisting of the eigenvalues and eigenvectors of the image are known, the original image and the secret data can be restored, but it is difficult for a third party who cannot know them to change the component to insert the secret data. This makes it possible to enhance the ability of data hiding based on multi-resolution analysis to protect information in secret data.

Cartesian coordinates and oblique coordinate representations in a two-dimensional plane are

$$W = X + Y\cos(\theta) \quad (1)$$

$$Z = Y\sin(\theta) \quad (2)$$

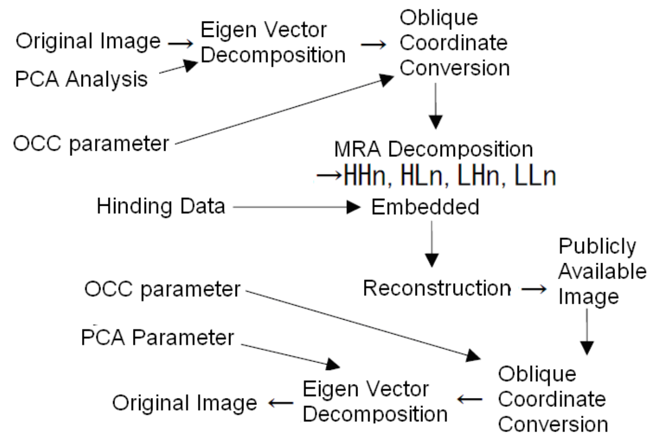


Fig. 3. Process Flow of the Data Hiding based on MRA using Eigen Vector Decomposition (or Principal Component Analysis (PCA)) and Coordination Conversion from Cartesian to Oblique Coordination Systems.

where *W*, *Z* is each axis in the oblique coordinates, *XY* is each coordinate in the Cartesian coordinates, and θ is the angle of the coordinate axes in the oblique coordinate transformation. An example of this is shown in Fig. 4.

In the figure, the red and green two-dimensional pixel distributions (scatter diagram) of the original image are transformed into two-dimensional coordinates composed of the first principal component axis PC1 and the second principal component axis PC2 orthogonal to it. Also, the Cartesian coordinates consisting of PC1 and PC2 are converted to the diagonal coordinates of the diagonal angle θ consisting of PC1 'and PC2'.

At this time, if the diagonal angle is changed without changing the quantization step, pixel definition is performed. The extreme example is when the domain is below the quantization step. In this case, only the quantization noise is transmitted, and no information is transmitted. The domain can be expanded (e.g. the pixel value is doubled when changing the oblique angle in the range of 90 degrees ± 45 degrees) and reduced when restoring the original image and the secret data. A reversible process, and this enlargement / reduction rate is known by only for content owners. Therefore, the only content owners can fully restore the original image.

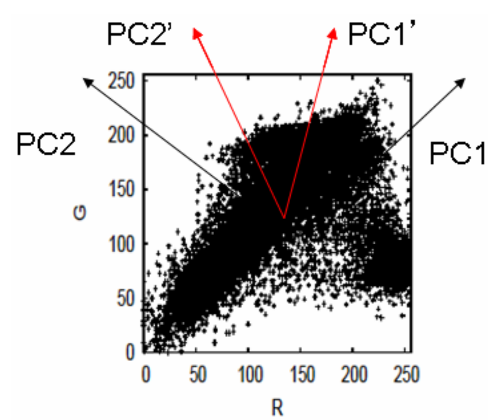


Fig. 4. PCA and Oblique-Coordinate Conversion (OCC) as a Preprocessing of the MRA based Data Hiding.

Next, the method of decrypting the secret data is explained. The first principal component image is used for the distribution image by using the coefficient when the principal component conversion is applied to the multidimensional original image before the secret data is hidden. Is implemented and wavelet decomposition is performed on the first principal component image. Decoding the secret data by the proposed method transforms the principal component transform into the multidimensional original image before hiding the secret data information. Decoding is possible only when the coefficients used are known, that is, the coefficients of principal component transformation differ depending on the multidimensional original image before hiding the secret data.

III. Experiments

An example of the experiment is shown as follows. I also used the Mandrill (Fig. 5), which was also selected from the standard image database for data compression evaluation (SIDBA), as the original image, and the time series data shown in Fig. 6 as the secret data. (Graph) was used.

The red, green, and blue primary color images of this color primary image are shown in Fig. 7. Here, the blue component is set to 0, and for the sake of convenience, it is used as two-dimensional multispectral image data. Fig. 8 shows the scatter diagram of the mean vector and transform coefficient matrix for performing the principal component transformation from the red and green two-dimensional scatter of the original color image, that is, the eigenvalue and the eigenvector, respectively.

λ =(133.772, 129.297)

V=|0.835 0.550|

|− 0.550 0.835|

Only I who owns the original image knows these accurate eigenvalues and eigenvectors (principal component conversion parameters), and even if the eigenvalue expansion is performed based on the circulation image, the restored image when the correct eigenvalues / eigenvectors are used. However, if the confidential data is image data with high redundancy, it is possible to recover the confidential data within the allowable error range and it is not enough. In order to enhance the confidentiality, I decided to add the oblique coordinate transformation as a pre-processing.

Convert the Cartesian coordinate axes after principal component conversion to any diagonal coordinate axes using the above Eqs. (1) and (2), where the diagonal angle of the diagonal coordinate axes is the diagonal coordinate transformation parameter θ. θ = 90 degrees is the orthogonal coordinate axis itself after the principal component conversion, and for example, if oblique coordinate conversion is performed with θ = 110 degrees and 70 degrees, Fig. 8 becomes Fig. 9. This diagonal angle can be arbitrarily set up to the range of the quantization step as described above, but the scaling ratio of the pixel value domain is changed depending on this angle. Therefore, it is necessary to adjust the quantized bit accordingly, and it is necessary to increase the processing resource, so I set it here to about ± 20 degrees. Restoration is extremely difficult because there is no information such as the diagonal angle and eigenvalue vector.

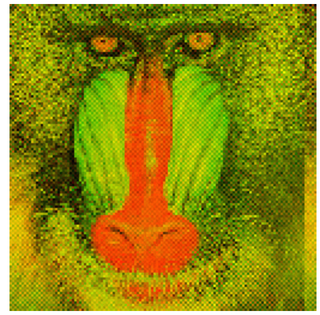


Fig. 5. Original Image of Mandrill of SIDBA Database for Data Compression Algorithm Evaluation.

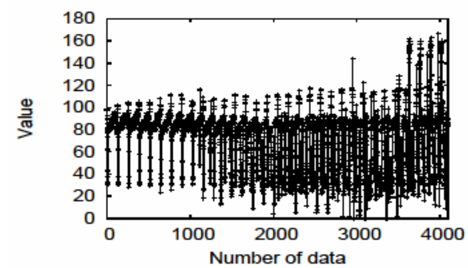


Fig. 6. Hiding Data of Image (Time Series of Data Graph).

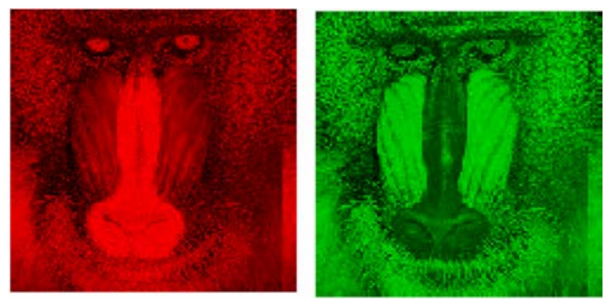


Fig. 7. Red and Green Colored Images of the Original Colored Image of Mandrill (Fig. 5).

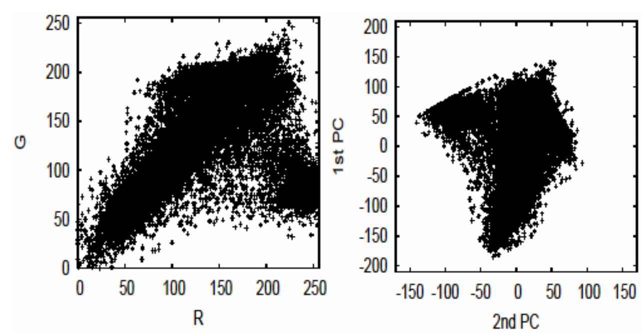
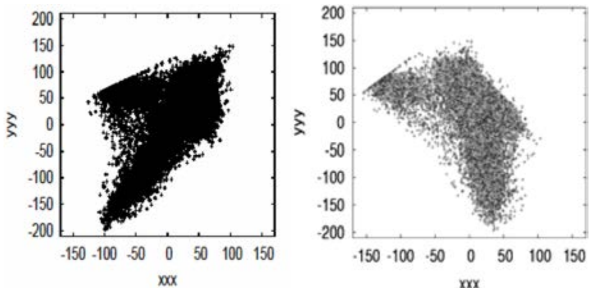


Fig. 8. Scatter Diagrams of the Original Red and Green Coordinate System and that of the First and Second Components Coordinate System.

It is shown that the protection performance of the secret data is improved by the parameter θ. Therefore, I try to estimate the secret data from the first principal component image in Fig. 10 by using the wavelet transformation. The information of the wavelet basis and the component (for example, the HH1 component) in which the secret data is embedded is known by some method, i.e., the information such as the eigenvectors held by the parties and the parameter θ are known. The third party is unknown.



(a) 110 degree (b) 70 degree

Fig. 9. Oblique Coordinate Converted Scatter Diagrams with 110 and 70 Degrees.

Fig. 10. Widely Available Image of which Hiding Image (Time Series of Data Graph) is hidden in the Original Image (Mandrill).

Fig. 11 shows the RMS deviations when secret data is embedded by changing the oblique coordinate transformation parameter θ and a third-party attempts to estimate secret data from the distribution data for each distribution data.

The RMS deviation when a third-party attempts to estimate the secret data from the distribution data depends on θ, that is, θ increases the confidentiality of the secret data. Therefore, it can be seen that the confidential data can be protected by protecting the information of the original image.

Next, I examine the degree of restoration of the secret data. I restored the secret data from the distribution image and evaluated the degree of restoration (mean squared error (RMS error) between the secret data and the restored secret data. The results are shown in Fig. 12. From this figure, it can be seen that the mean squared error between the original secret data and the secret data reconstructed from the distribution image increases. In other words, increasing the diagonal angle improves the confidentiality.

It is important for hiding. The degree of restoration of secret data was evaluated when noise due to image processing, removal attacks, etc. was included in the distribution image. The noise included was 5 steps with a mean of 0 and a standard deviation sigma of 5-20. After superimposing the normal random number changed in step 1, the secret data was reconstructed and the mean square error from the original secret data was evaluated. The results are shown in Fig. 13.

The mean square error increases steadily by the amount of superimposed noise, and the mean square error increases by about 10% by changing the oblique coordinate angle from 90 degrees (orthogonal coordinates) to 110 degrees. Therefore, there is no resistance to noise, and it is found that the restored secret data deteriorates by the amount of superimposed noise, and the effect of oblique coordinate transformation is about 10%. Although it is possible, the quantization error due to requantization after coordinate transformation increases, so it was judged that the limit is about 70 to 110 degrees.

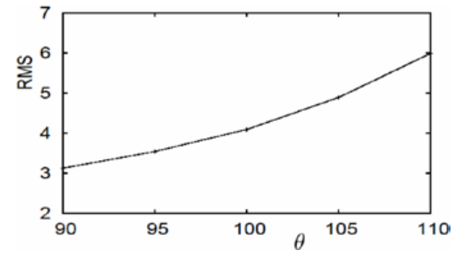


Fig. 11. Root Mean Square difference between Original and Distributing Image of the Proposed Watermarking with 90 to 110 Degrees of OCC.

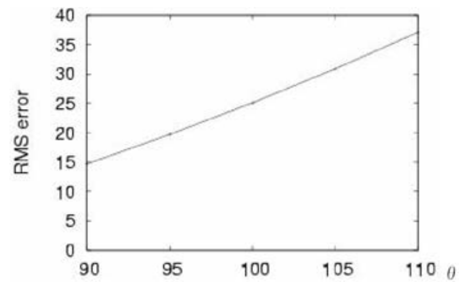


Fig. 12. RMS Error between Original and Restored Hiding Data Derived from the Distributing Image.

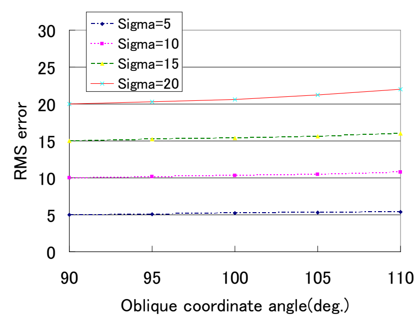


Fig. 13. Hiding Performance for which Normal Distributed Noise with Zero mean and Standard Deviation Ranges from 5 to 20 (5 Step) is Added to the Distributing Image.

IV. Conclusion

Data hiding method with Principal Component Analysis (PCA) and image coordinate conversion as a preprocessing of wavelet Multi Resolution Analysis (MRA) is proposed. The method introduced in this paper allows only I who knows the characteristics of the original multispectral image to recover the secret data, i.e., when the information of the original image needs to be protected. In this paper, the Daubechies basis function is adopted as the wavelet, but the secret data can be restored by using the biorthogonal wavelet, and the secret data can be protected by hiding what is adopted as the biorthogonal wavelet.

Through experiments, it is found that the proposed method is superior to the conventional data hiding method without any preprocessing. The method introduced in this paper allows only the owner of the original image who knows the characteristics of the original multispectral image to recover the secret data, i.e. when the information of the original image needs to be protected. Moreover, in the introduced method, the information of the secret data is protected by the existence of the eigenvector and the oblique coordinate transformation, that is, the secret data is restored if at least the information of the true original image is not known. The principal component transformation coefficient differs for each original image and is composed of the eigenvectors of the original image.

I have introduced a method that improves the confidentiality by applying principal component transformation and oblique coordinate transformation as preprocessing for data hiding based on wavelet multiresolution analysis. I investigated the confidentiality when a third-party attempts to extract secret data from only the data for distribution.

The proposed data hiding method can be applicable for all the images in the world. There is no limitation in terms of applicability at all.

V. Future Research Works

In the future, I will compare the proposed method with conventional data hiding methods such as steganography method. Influences on the restoration process due to tampering on the secret image hidden imagery data has to be investigated.

Acknowledgment

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DCRL: Approach for Pattern Recognition in Price Time Series using Directional Change and Reinforcement Learning

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***Abstract*—Developing an intelligent pattern recognition model for electronic markets has been a vital research direction in the field. Ongoing research continues for intelligent learning algorithms capable of recognizing and classifying price patterns and hence providing investors and market analysts with better insights into price time-series. In this paper, an adaptive intelligent Directional Change (DC) pattern recognition model with Reinforcement Learning (RL) is proposed, so called DCRL model. Compared with traditional analytical approaches that uses fixed time interval and specified features of the market, the DCRL is an alternative intelligent approach that samples price time-series using an event-based time interval and RL. In this model, the environment's behavior is incorporated into the RL process to automate the identification of directional price changes. The DCRL learns the price time-series representation by adaptively selecting different price features depending on the current state. DCRL is evaluated using Saudi stock market data with different price trends. A series of analyses demonstrate the effective analytical performance in detecting price changes and the extensive applicability of the DCRL model.**

Keywords—Machine learning; reinforcement learning; directional-change event; pattern recognition; stock market

I. INTRODUCTION

Pattern recognition in financial markets has been widely studied in the fields of finance, economics, computer science, engineering, modern physics, and mathematics [30,31,37,38,48,51]. Furthermore, artificial intelligence and Machine Learning (ML) have been widely used for financial market forecasting, pattern recognition, and event detection to provide decision support in various financial market segments [19,28,32,40,42].

In the financial literature, most developed ML algorithms and methods are based on physical time, for which prices are sampled at fixed time intervals (such as daily, hourly, etc.) [26,27]. To avoid the discontinuous nature of the price time-series, the Directional Change (DC) event approach provides an alternative method for sampling time-series data [6,27]. A price point is sampled when a significant price change in the price trend is observed. Therefore, the DC event approach represents a time-series as downtrend or uptrend events based on the magnitude of price changes. Several studies have been developed based on the DC event approach for pattern recognition [26], profiling price time-series [10,46], regime change detection [47], event detection [2], time-series analysis [7,33], forecasting models [15,16], and designing trading strategies [3,4,8-14, 29,50].

Reinforcement Learning (RL) is a learning method used for sequential decision-making problems [44]. RL is one of the three basic ML methods, along with supervised and unsupervised learning. In RL, the learning agent interacts and adapts from environmental interactions by exploitation or exploration. RL achieves performance improvements through continuous evaluations of and interactions with the environment [45]. RL has the advantages of self-learning and adapting to the environment towards decision making but lacks, to a certain extent, the environment's awareness capability. Despite the effectiveness of the RL approach, event detection and pattern recognition remain challenging in real-world time-series analysis for three reasons. First, using a physical time interval makes the price time-series discontinuous, given that prices are transacted at irregular times. Second, RL can be designed with a complex structure and a large number of parameters, which can interrupt the analysis. Lastly, the learning process of the dynamic continuous market environment's state representation and the associated learning strategy affect the RL model's interruption and converge.

In this work, an intelligent intrinsic time-driven model for automatic event detection in a price time-series - the Directional Change Reinforcement Learning (DCRL) - is developed. The DCRL is presented in two sequential phases: the RL phase and the DC event analysis phase. In particular, in the RL phase, the RL algorithm learns the environmental states and features to find the most applicable dynamic threshold for the DC event analysis. The aim is to find the best dynamic threshold definition method using the RL agent, which is subsequently used for DC event detection. We used the dynamic threshold introduced in [2], which replaces the DC given fixed threshold. For the DC event analysis phase, the generated threshold from the former phase is used to detect DC events in the price time-series. The proposed model is evaluated using the Saudi stock market (Tadawul). Stocks with different price trends and series patterns are selected to evaluate the model's performance. The experimental results demonstrate that the model is adaptable to various market conditions and might be used for designing algorithmic trading.

We are interested in developing an intelligent event detection (i.e. significant price movement) algorithm from a price time-series. This algorithm will allow investors or even artificial software agents to detect price movements in the market to capture investment opportunities. Hence, our motivation is that the DCRL can provide decision support methods for analysts and investors and can facilitate the automation of event detection for sampling price time-series. Therefore, a novel method for financial event detection and time-series sampling has been proposed.

The remainder of this paper is organized as follows. Section II reviews several related works in the financial literature. Section III introduces the proposed DCRL model. Section IV describes the datasets, presents the empirical evidence of learning and identification of events, and evaluates the effectiveness and robustness of the DCRL. The last section concludes the paper and presents some future directions.

II. Related Work

In the financial literature, several studies including but not limited to the following have been using the RL method for financial signal representation [32], designing trading strategies and algorithmic trading [17, 20, 32, 41], portfolio management [5], optimizing trade execution [39], trading systems [49], Foreign Exchange (FX) asset allocations [22], cryptocurrency market trading [18], and changes in market regimes [5].

Supervised learning methods have been used to forecast stock prices and the direction of price trend movements [21]. Several studies used deep ML methods to forecast a stock price using historical numerical and textual data [1,23]. The authors in [23] used deep learning for event-driven stock predictions. The events are extracted from news text and formulated as dense vectors that are trained using a neural tensor network. The deep convolutional neural network is used to model the events' impact on price time-series movements. The results showed that the proposed model could obtain an approximate 6% improvement in S&P 500 index forecasting. Nonetheless, the proposed method is challenging if attempting to achieve adaptable learning and simultaneously lacks the quick response to new dynamic market conditions given the high cost of retraining [32]. Thus, when designing event detection algorithms and algorithmic trading, the inherent characteristics and evolution of market fundamentals should be considered.

The RL method might be an alternative solution for event detection and algorithmic trading, given that it is more applicable for continuous decision making in financial market trading [32]. Bertsimas and Lo in [17] examined the application of RL for trading large blocks of equity over a specific period to minimize the expected cost of executing trades. Their results demonstrated that the RL trading strategy saved between 25% and 40% in execution costs relative to the naïve strategy. Experimental results in [20,41,43] also show that the adaptive event detection mechanism and algorithmic trading with RL methods achieve more stable returns. The experimental results by [18] confirmed the effectiveness of deep RL methods on a dataset of one of the largest cryptocurrency markets in the world, achieving average daily returns of over 24%.

Studies on algorithmic trading using the RL method can be categorized into two main groups: policy-based methods and value-based function methods. Work in [31] has designed an on-policy (policy-based) and an off-policy (Q-learning) discrete state and action RL agents for an individual retirement portfolio. Their study found that using the trading algorithm design results in the on-policy algorithm maintaining better evaluation and adaptation to the environment than Q-learning. Their study also found that the on-policy method's drawback is that it continuously remains to explore in the environment even when the best solution is learned. The works in [22,36] has demonstrated that the benefit of the policy-based model is that it has better results than the value-based function model.

The authors in [32] studied the representation of the stock market environmental state and developed a trading strategy using historical stock price and trading volume data. They developed a time-driven, feature-aware model jointly with a deep reinforcement learning model (TFJ-DRL) that had two parts - deep learning perception and RL decision making - to improve financial signal representation learning and, hence, decision making in algorithmic trading. The results showed that the TFJ-DRL model outperformed the state-of-the-art methods in the literature. A similar study by [24] introduced a decision support algorithm to filter trading signals based on RL and neural networks. The study aims to detect seasonality events of the basic strategy to improve the reward to risk ratios.

Maringer and Ramtohul in [34,35] introduced a regime-switching to the Recurrent RL (RRL), where regime-switching captures the different price trend movements over a time series. The results highlighted that the regime-switching RRL outperforms the traditional RRL when the price time series exhibits noticeably different regime characteristics. The RRL model in [36] is a policy-based model that offers the action of the previous time's trading with the current environmental state to direct RL, hence, create a trading action. This model's main obstacle is the direct input of all of the environmental features to the RL model without awareness and representation of the current environment's status. The study by [25] combined features based on Japanese candlesticks, a technical analysis technique, with RRL to produce a high-frequency algorithmic trading system for the E-mini S&P 500 index futures market. The results demonstrated a significant increase in both return and Sharpe ratio compared to relevant benchmarks, suggesting the capability of RRL to detect events in a high-frequency equity index futures trading environment.

Overall, the RL method has been recognized as being effective and efficient in forecasting asset prices in financial markets and, hence, make trading decisions. Previous studies used RL based on physical time, which is characterized by a fixed time interval, whereas the price time series is irregularly spaced in time. Therefore, to develop an adaptive RL algorithm for event detection, the DC event approach is used to represent and study the price time series. In this work, we use the RL to enhance the dynamic threshold definition method presented in [2]. We want to improve the dynamic threshold definition method so that we can set the dynamic threshold without the need for an additional source of data (such as news).

III. Methodology

In this section, we introduce the DCRL model which aims to identify financial events from stock market price time series and, hence, represent periodic patterns of the price time series. First, the DC event approach which constructs a price time series of continuous DC events is described. Then, the process of defining the DC dynamic threshold is explained. Finally, the DCRL model is introduced as a dynamic adaptive process to select the optimal equation for the DC dynamic threshold. In other words, a DCRL model is developed to identify DC events in a price time series using the different dynamic threshold equations (actions). Therefore, the goal is to improve the reward function under different states.

A. DC Event Approach

Using the DC event approach, price time series data are sampled at irregular time intervals using a given size threshold (λ), which is defined by the observer (fixed value) and is typically expressed as a percentage [6]. Thus, the DC event approach transforms the discrete nature of the price time series into continuous DC events independent of the notion of fixed physical timescales. Under the DC event approach, the price time series is summarized into alternating uptrend and downtrend DC events.

A DC event is identified as a confirmed price change that is larger than, or equal to, a predefined threshold (λ) [6]. A DC event can be either a downturn or an upturn DC event. The time interval between an upturn DC event and the next downturn DC event is called an upward run, whereas a downward run is the time interval between a downturn DC event and the next upturn DC event. During an upward run, the last high price (p_h) is continuously updated to the maximum value between the current asset price p(t) and the last high price (p_h). In a downward run, the last low price (p_l) is continuously updated to the minimum value between the current market price p(t) and the last low price (p_l) At the beginning of a data sequence, the last low price (p_l) and last high price (p_h) are set to the initial asset price p(t_0) at time t_0. An upturn DC event is detected during a downward run and, in particular, when the current asset price p(t) exceeds the last low price (p_l) by a given threshold (λ); refer to Formula (1). In contrast, a downturn DC event is detected during an upward run when the current asset price p(t) is lower than the last high price (p_h) by a given threshold (λ); refer to Formula (2).

$$p_t \geq p_l \times (1 - \lambda) \quad (1)$$

$$p_t \leq p_h \times (1 - \lambda) \quad (2)$$

The DC event approach captures the short-term dynamics of the price time series by detecting significant events and a clear picture of the time series behavior on the basis of the observer's needs. Most importantly, this approach reduces the complexity of the financial market price time series, given the defined dataset of periodic price points to study and evaluate. The selected threshold value controls the magnitude of the DC price events in a time series. Therefore, choosing a substantial threshold results in fewer detected DC price events, whereas a small threshold maps a series of insignificant patterns. The authors in [6] described the core mechanism of the DC event approach to study the financial price time series. In this work, a price time series is formulated using the DC event approach. Given a size threshold (λ), the mission is to detect events at the DC confirmation point regardless of whether or not the direction of the price trend changes at a certain point.

B. DC Dynamic Threshold

In this section, we describe the dynamic threshold definition method which replaces the DC fixed given threshold value [2]. The dynamic threshold definition method is suitable for markets that operate during specific opening and closing times (such as stock markets). The dynamic threshold is a flexible value and brings with it the advantage of allowing the identification of price changes (i.e., DC events) of different magnitudes in continuously changing environments.

In [2], significant price fluctuations were considered as an event occurrence indicator. Thus, the dynamic threshold definition method depends on the previous day's price behavior (short-term price history). The daily dynamic threshold value can be set in three possible ways, choosing the most appropriate one was not straightforward. They depend on an alternative source of data (news outlets) to facilitate the definition of the dynamic threshold. A suitable dynamic threshold definition method can be selected depending on the investigated asset news and market conditions. In this work, the best method for defining the dynamic threshold value without an alternative source of data is determined using RL. Hence, an agent is developed to select the most effective dynamic threshold definition method (i.e., the one that detects DC events at the right time).

Basically, the dynamic threshold can be set using one of the three equations (Eq. (3), Eq. (4), and Eq. (5)) as follow:

DT_Overnight=Up/Downward_ROC+Overnight_ROC (3)

DT_PreviousDay=Up/Downward_ROC+
PreviousDay_ROC (4)

DT=Up/Downward_ROC+PreviousDay_ROC+
Overnight_ROC (5)

DC dynamic threshold depends on the price Rate Of Change (ROC) between the DC p_h/p_l (refer to Section III.A) and the high/low prices (depending on the examined trend) for the current day. In addition, it finds the price ROC for the previous day (between the previous day's opening and closing prices), and the price ROC that occurred overnight (between the previous day's closing price and the current day's opening price). The dynamic threshold is defined by the sum of the aforementioned metrics, as shown in Eq. (5). However, in some circumstances in which something has happened the previous day or overnight, the shortened version of the dynamic threshold definition method (Eq. 3 or Eq. 4) is used to ensure a reduced threshold value that certainly increases the chance of identifying a DC event (either an upturn or downturn event). Also, to be mentioned is that if a defined threshold value by Eq. (5) was found to be less than 0.01, then we use the previous day's defined threshold instead. This approach is taken because we are almost certain that nothing has happened (experiencing a stable situation as no significant price changes occurred on the previous day or overnight), and an exceptionally low threshold value may detect a spurious or insignificant event.

C. DCRL

In this section, we introduce the DCRL model, which can identify financial events from a time series. The DCRL is based on the RL approach, which directs the dynamic thresholds definition method, and the DC approach, which is responsible for detecting the occurring DC events on the basis of the given threshold value from the RL phase.

RL is a learning approach through which an intelligence algorithm represented by an agent is designed to learn from interactions with the environment. Therefore, RL mimics human learning and, hence, appears well suited to processing the price time series. The goal is to train the RL agent based on a sequence of interactions to learn an optimal policy from the interaction to maximize the total cumulative reward obtained. In this section, the RL approach's key elements are introduced, and the approach is tailored to the goals of this study.

RL can be generally categorized into two types: the policy-based and value-based function methods [32]. Policy-based RL explicitly and directly builds a representation of a policy from the environment and, hence, creates continuous decisions from the policy. The established policy is stored in memory during the learning phase. The DCRL policy-based method is as follows: if the price ROC from the previous day or overnight is greater than a five-day price change moving average, then the first two equations (Eq. 3 or Eq. 4) from section III.B are used; otherwise, Eq. (5) is used.

The RL approach consists of the environment, agent, state, action, and reward. Considering discrete times $t = 0, 1, 2, 3,\ldots$, at each time t, a RL agent receives some representations of a state in the environment, denoted by $s_t \in S$, where S is the set of all possible states. Based on the current state s_t and the previously obtained information, the agent takes action $a_t \in A(s_t)$, where $A(s_t)$ is the set of actions available in state s_t. The space of actions in DCRL consists of the three equations for defining the DC dynamic threshold, as described in Section 3.2. The RL agent chooses an action on the basis of its policy π_t, which is a mapping from each state to the probabilities of deciding on each possible action. Therefore, π_t (s) denotes the chosen action when $S_t = s$ based on π_t. At the next time point $t+1$, the agent receives a numerical *reward* from the environment, denoted by $r_t \in R$, *because of its action* a_t *and* moves to a new state s_{t+1}. Based on the earned reward, the RL agent learns to adapt its actions on the basis of the market condition to maximize its future rewards.

The DCRL agent interaction with its environment is depicted in Fig. 1. As an input, we have the price time series, and as an output, we get the optimal chosen action a_t (the best dynamic threshold definition method) and the assigned reward r_t. The agent interaction with the environment is shown in the stage between input and output. Table I provides the set of all possible states in the environment and the set of actions presented for each state s_t, along with the associated rewards for each pair of state and action. In Table I, the DCRL approach takes the appropriate state-action policy π_t (s_t, a_t), which indicates the expected reward r_t for each possible action a_t. For this purpose, the DCRL agent starts with random initial values of π_t (s_t, a_t) for $s_t \in S$ *and* $a_t \in A(s_t)$. The DCRL agent then proceeds with the aforementioned interaction learning steps: (1) observes the current state s_t of the price time series, (2) executes action a_t, and (3) receives reward r_t and observes the next state s_{t+1}.

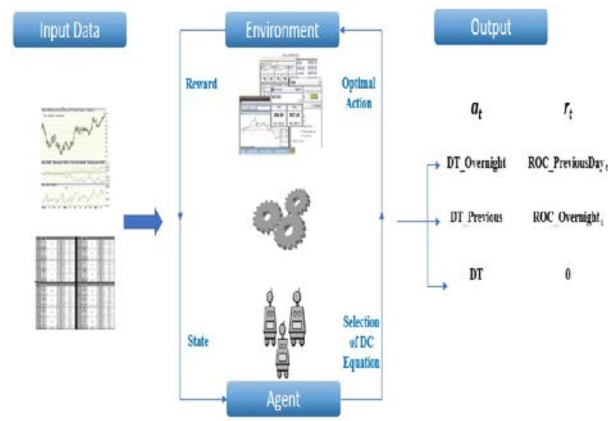

Fig. 1. DCRL Model Interaction with its Environment.

In each iteration, the DCRL agent observes the current state of the environment using the following state variables: a five-day price change moving average, the previous day opening and closing prices, and the previous day closing price and current opening price. This specification has established a learning architecture whereby the previous action at time $t-1$ is considered. In this study, we choose the previous day ROC (Ext_Previous$_t$), overnight ROC (Ext_Overnight$_t$), and Neutral (Neutral$_t$) state to represents the set of possible states S. Following the observation of the current state s_t, the RL agent chooses action a_t from three possibilities. (1) Equation 3 (DT_Overnight) is used to define the DC dynamic threshold considering that an overnight event has occurred. (2) Equation 4 (DT_PreviousDay) is used to define the DC dynamic threshold considering that an event has occurred during the previous day. These two possible actions are associated with the two states Ext_Previous$_t$ and Ext_Overnight$_t$. Note that an action that offers a lower threshold value is selected because it will increase the chance of detecting an event. For the Neutral$_t$ state, only one possible action exists, which is (3) using Equation 5 assuming that no extreme price changes have occurred. Hence, the following set of possible actions is obtained: a_t = { DT_Overnight, DT_PreviousDay, *DT}*.

The agent receives a reward on the basis of the selected action. The reward is the maximum of either ROC_PreviousDay or ROC_Overnight when actions DT_Overnight or DT_PreviousDay are chosen. Alternatively, no reward is assigned (reward = 0) when action DT is taken because it is always taken whenever action DT_Overnight or

DT_PreviousDay cannot be taken. More specifically, if action DT_Overnight was executed, then the assigned reward is ROC_PreviousDay; because the action was based on the lowest threshold value and was DT_Overnight (it led to the lowest threshold value), then the reward is ROC_PreviousDay because it is of greater value than ROC_Overnight. The same applies for action DT_PreviousDay: if action DT_PreviousDay was executed, then the reward assigned is ROC_Overnight.

TABLE I. SET OF ALL POSSIBLE STATES IN THE ENVIRONMENT AND SET OF ACTIONS PRESENTED FOR EACH STATE S_T ALONG WITH ASSOCIATED REWARDS FOR EACH PAIR OF STATE AND ACTION

S_t	S_{t+1}	a_t	*P*	*R*
$Ext\_Overnight_t$	$Ext\_Overnight_{t+1}$	DT_Overnight	0.33	$ROC\_PreviousDay_t$
	$Ext\_Previous_{t+1}$	DT_Overnight	0.33	$ROC\_PreviousDay_t$
	N_{t+1}	DT_Overnight	0.33	$ROC\_PreviousDay_t$
$Ext\_Overnight_t$	$Ext\_Previous_{t+1}$	DT_PreviousDay	0.33	$ROC\_Overnight_t$
	$Ext\_Overnight_{t+1}$	DT_PreviousDay	0.33	$ROC\_Overnight_t$
	N_{t+1}	DT_PreviousDay	0.33	$ROC\_Overnight_t$
$Ext\_Previous_t$	$Ext\_Previous_{t+1}$	DT_PreviousDay	0.33	$ROC\_Overnight_t$
	$Ext\_Overnight_{t+1}$	DT_PreviousDay	0.33	$ROC\_Overnight_t$
	N_{t+1}	DT_PreviousDay	0.33	$ROC\_Overnight_t$
$Ext\_Previous_t$	$Ext\_Overnight_{t+1}$	DT_Overnight	0.33	$ROC\_PreviousDay_t$
	$Ext\_Previous_{t+1}$	DT_Overnight	0.33	$ROC\_PreviousDay_t$
	N_{t+1}	DT_Overnight	0.33	$ROC\_PreviousDay_t$
$Netural_t$	N_{t+1}	DT	0.33	0
	$Ext\_Overnight_{t+1}$	DT	0.33	0
	$Ext\_Previous_{t+1}$	DT	0.33	0

IV. DATA AND EMPIRICAL RESULTS

To verify the effectiveness and robustness of the proposed DCRL model, a series of experiments were conducted using four price datasets for stock exchange indices. The DCRL utilizes a policy-based model that learns the policy from historical prices and defines a variety of continuous actions according to the learned policy. A descriptive analysis of the identified events is presented in Section IVB, it shows a discussion of the identified events along with a statistical description of the associated DC dynamic threshold values. The last section presents the evaluation results of the effectiveness and accuracy of the proposed DCRL model.

A. Data

Our empirical study relies on data from the Saudi stock market (Tadawul[1]) for the period from March 2015 to March 2020, the total number of investigated days is approximately 1285 days. We used four stock indices for the following two financial sectors: Al Rajhi, Alinma, and SABB banks (Sector: Financials Industry, Group: Banks), and STC (Sector: Telecommunication & Information Technology). These selected stock indices are well known in the Saudi financial market. The price time series for these four stock exchange indices are sourced from Yahoo finance[2]. Each row data includes the date along with opening, low, high, and closing prices. The choice of these four stock indices is based on the strength of their economic and financial factors. The distribution of each dataset composes of a variety of price trends and a series of patterns, which will contribute to the effectiveness of evaluating the DCRL model under different situations. Fig. 2 shows the price time series for the four stock indices during the five investigated years (2015- 2020).

Table II presents the basic annualized average summary descriptive statistical analysis of the datasets for the four stock exchange indexes during the period from March 17, 2015, to March 13, 2020. The mean (μ), standard deviations (σ), Skewness, Kurtosis, minimum, and maximum price values are reported for each stock index.

B. Results

In Table III, we report the statistical analysis results of the identified DC events using the DCRL model. Table III provides the average annualized of the following quantities: number of identified DC events, number of times (days) the previous day's defined threshold was also used for the current day, number of times an event was identified as the ROC taking place overnight was significant, and the number of times an event was detected as the ROC taking place the previous day was significant. When *DT_Overnight* and *DT_PreviousDay* are used more often to define the DC dynamic threshold, this use could mean that the price changes occurring overnight (between the previous day's and the current day's opening prices) or occurring on the previous day (between previous day opening and closing prices) are considerably high. Therefore, the identified DC events using the dynamic threshold definition method can capture the sensitivity of the market changes and, hence, the identification of potential events.

TABLE II. DESCRIPTIVE STATISTICS OF FOUR STOCK INDICES: ALRAJHI, ALINMA, SABB, AND STC. THE PERIOD SPANS FROM MARCH 17, 2015, TO MARCH 13, 2020, AND THE TOTAL NUMBER OF INVESTIGATED DAYS IS APPROXIMATELY 1285 DAYS

Index	μ	σ	Skewness	Kurtosis	Min.	Max.
Alrajhi	48.25	3.64	0.38	-0.37	40.20	56.39
Alinma	18.99	2.12	-0.17	-0.22	13.92	22.64
SABB	28.87	3.34	-0.059	-0.53	21.06	34.78
STC	77.95	5.38	0.16	-0.09	65.53	90.07

[1] https://www.tadawul.com.sa
[2] https://finance.yahoo.com/

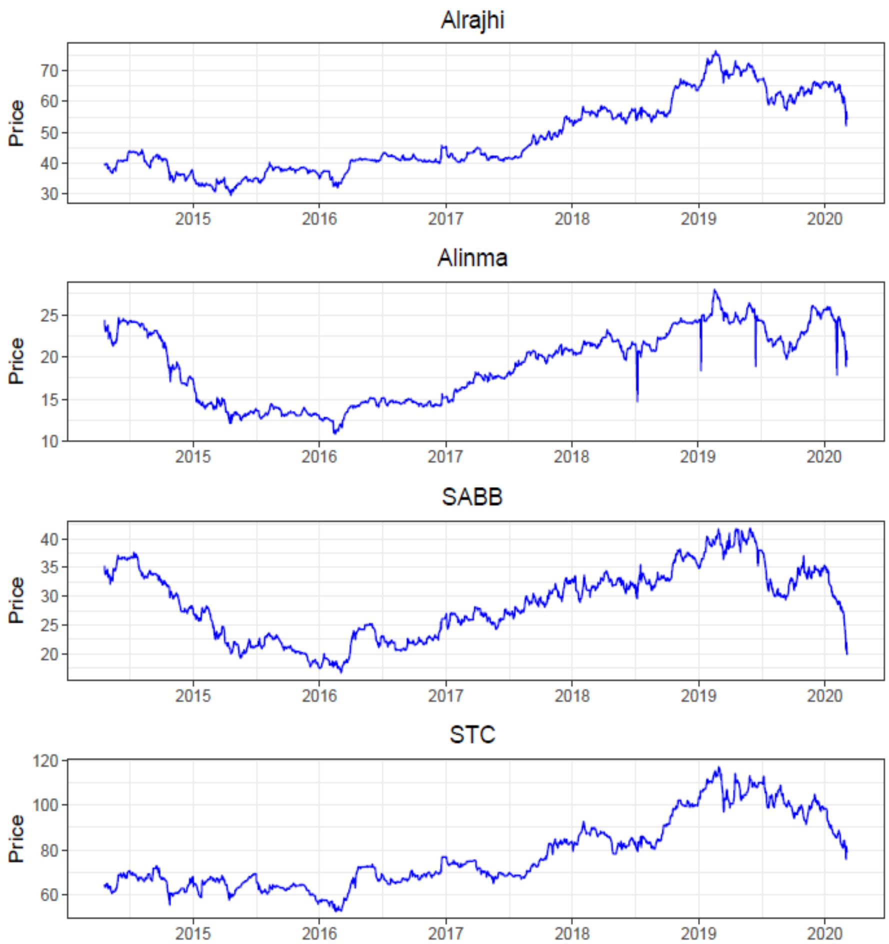

Fig. 2. Price Time Series for the Four Stock Indices: Alrajhi, Alinma, SABB, and STC over the Period from 17/3/ 2015-13/7/202 (x-axis Represents Price and y-axis Represents Year).

For all of the investigated stocks during the 5 examined years, more than half of the detected DC events from the dynamic threshold values were found using both equations DT_Overnight and DT_PreviousDay. Specifically, these equations have detected more than 60% of the DC events in Alinma and STC, and 70% of the DC events in Alrajhi and SABB, refer to Table III for a summary of the annualized average statistical analysis results. In addition, SABB had the fewest number of days on which the previous day defined threshold was also used for the current day to identify DC events (if any), on average, only 14% of the investigated days the previous day threshold was also used for the current day. In other words, on average each year in 221 days out of the 259 days, a new dynamic threshold was set each day to detect DC events, if any. Therefore, SABB may have been exhibiting a number of price variations; refer to SABB price time series in Fig. 2.

Also, the high number of identified DC events (an average of 54 DC event each year) confirms this phenomenon. In contrast, Alrajhi, Alinma and STC had a higher number of days for which the previous day threshold was again used for the current day (at least 25% of days); refer to Fig. 2 for Alrajhi, STC and Alinma price time series, which also maintains a number of price stability trends.

In order to have a deeper and closer look, in Fig. 3, we illustrate in more details the identified DC events using DCRL over the period from March 2019 to March 2020 for Alrajhi, Alinma, SABB, and STC price time series. The X-axis represents the date, and the Y-axis represents the daily closing price. In the chart, the square-shape event represents a downturn DC event, and the x-shape event represents an upturn DC event. Forty-nine DC events were identified from Alrajhi and STC. In addition, Alinma had 45 identified DC events, and 57 DC events were detected in SABB (refer to Fig. 3).

TABLE III. STATISTICAL ANALYSIS RESULTS OF AVERAGE ANNUALIZED IDENTIFIED DC EVENTS USING DCRL MODEL

Index	N_{DC}	$N_{\lambda(t-1)}$	$N_{\lambda(t)}$	**N(DT_Overnight)**	**N(DT_Previous Day)**
Alrajhi	51.4	66.4	192.2	17.4	18
Alinma	49.6	77.8	180.4	16.2	16
SABB	53.8	36	220.6	20.4	16.4
STC	49.8	63.8	192.6	19.8	14.4

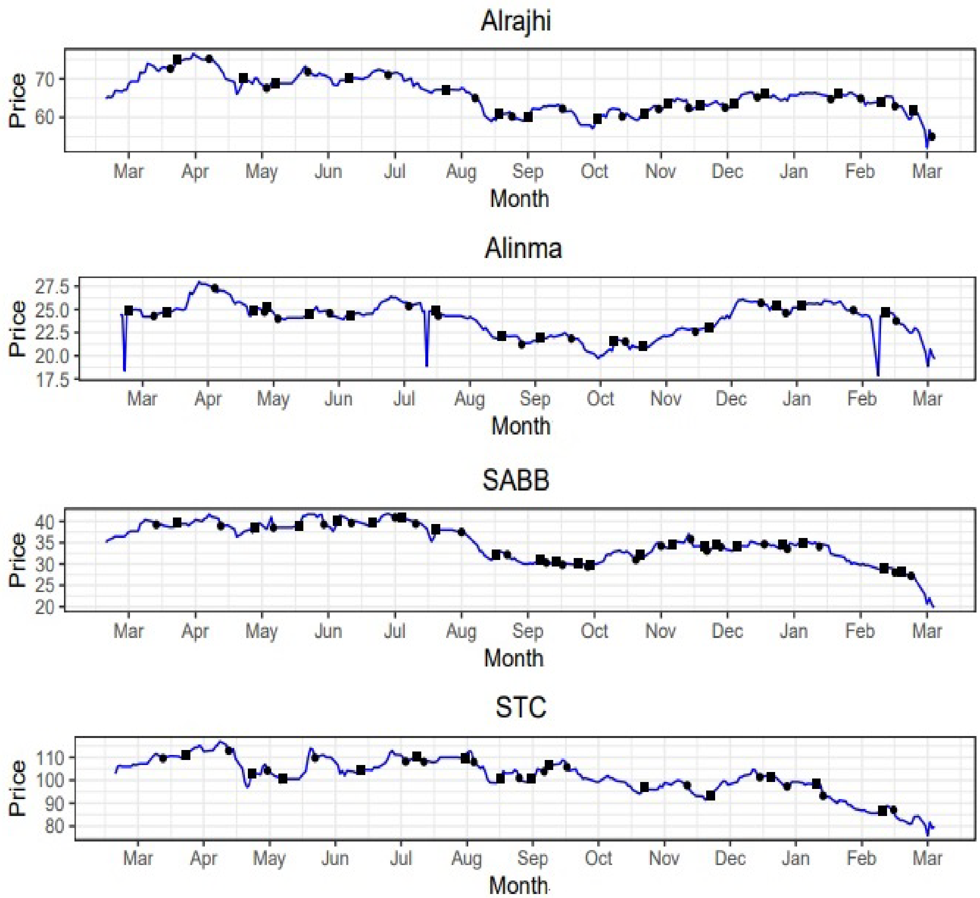

Fig. 3. Price Time Series for Four Stock Indices: Alrajhi, Alinma, SABB, and STC over the Period from March 17, 2019, to March 13, 2020. Identified DC Events (upward and downward) using the DCRL Model are shown for the Final Year in the Sampled Period.

Physical time (e.g., daily prices) fails to recognize the pattern flow of price movement, giving that the variety of price changes depends only on that considered time. Moreover, using daily or intraday prices to detect price patterns maps a range of patterns with different sizes, resulting in discontinuous pattern flow of price movements. On the other hand, the DC events reduces the complexity of a price time series giving that it detects periodic patterns in contrast to those detected by physical time.

Table IV reports an analysis of the defined DC dynamic threshold values and presents the mean value of the dynamic DC threshold values during the investigated period, the minimum and maximum DC dynamic threshold values, and, finally, the standard deviation values. Table IV clearly demonstrates that Alinma had a high standard deviation ($\sigma = 0.032$) relative to other stocks. This finding indicates that the defined threshold values are spread out with relatively high variations and are far from the mean. Additionally, Alinma has the highest maximum threshold (0.208), whereas all other stocks' maximum values were between 0.08 and 0.1 (Alinma's maximum value is at least two times higher than that of all of the other stocks); refer to Fig. 3 for the Alinma price time series to observe the significant price jumps encountered. For illustration, on March 18, 2019, the closing price was 24.4, which slipped to 18.3 on the next day. Subsequently, on March 20, 2019, the price bounced back to 24.4. During the investigated period, this significant jump occurred at least three times (in March and July 2019, and in February 2020). For the rest of the stocks, the standard deviation was between 0.012 and 0.016, indicating a smaller value. Thus, in these cases, the data points are close to the mean.

TABLE IV. DESCRIPTIVE STATISTICS OF THE DC DYNAMIC THRESHOLD VALUES DEFINED BY DCRL MODEL. FOUR DESCRIPTIVE VALUES ARE PRESENTED FOR DC DYNAMIC THRESHOLD: MEAN (μ), MINIMUM, MAXIMUM, AND STANDARD DEVIATION (Σ)

Index	μ	Min	Max	σ
Alrajhi	0.022	0.046	0.0893	0.012
Alinma	0.027	0.029	0.208	0.032
SABB	0.027	0.0102	0.109	0.017
STC	0.023	0.0109	0.085	0.013

C. Evaluation

To verify the effectiveness and robustness of the proposed DCRL model, we evaluate the results using the (i) length of the price-curve coastline, and (ii) accumulated reward value from the DCRL model. The length of the price-curve coastline offers an indicator of the usefulness of sampling the price time series, whereas the accumulated reward value evaluates the efficiency of the learning process in the DCRL model.

1) Price-curve coastline: The authors in [26] uncovered the scaling laws used to estimate the length of the price-curve coastline on the basis of the intrinsic time, which turns out to be long. A price-curve coastline can capture the price variations and, hence, the potential profit [26]. In this section, we measure the length of the price-curve coastline using two different models: DCRL (intrinsic time) and physical time (fixed time intervals). The goal is to evaluate their performance by summarizing the price movements and, thus, improves the understanding of the dynamic behavior of the price time series in a simplified manner.

The length of a price-curve coastline is defined by the sum of all price changes during a defined period *T*. Under intrinsic time, the length of the price-curve coastline during period *T* is the average of the price changes between the identified DC events [6]. The length of the price-curve coastline under the DCRL model *c(λ)* is defined by:

$$c(\lambda) = \frac{1}{N_{DC}} \sum_{i=1}^{N_{DC}} |p_i - p_{i+1}| \quad (6)$$

where N_{DC} is the number of identified events determined by the DC dynamic threshold (λ), p_i is the price of the *i*-th DC turning point, and p_{i+1} is the consequential DC turning point.

Under fixed physical time intervals, the length of the price-curve coastline during period *T* is the average of the price changes between the fixed points at which the time distance between all fixed points are equivalents [6]. The length of the price-curve coastline under physical time *c(t)* is defined by:

$$c(\mathrm{t}) = \frac{1}{n} \sum_{i=1}^{n} |p_i - p_{i+1}| \quad (7)$$

where p_i is the price at point *i* (refer to the table to observe the length of PTI for all investigates stocks), and *n* refers to the total number of fixed points, which equals the number of identified DC events (to ensure fairness in comparison).

It is essential to being aware with how well the established DCRL and the physical time price-curves fit the real price time series to evaluate their performance and effectiveness of sampling price changes in a time series. For instance, Fig. 4 shows the price time series for the STC index over the March 17, 2019, to March 13, 2020 (the blue solid line) and a zoom-in in the lower chart from November 24, 2019, to January 5th, 2020. The chart compares the price changes defined under the DCRL model (the red dashed line) and the physical fixed time interval model (the green dashed line) using the same number of points (49 DC events in DCRL and 49 points in the physical time scale). The DCRL model can identify price movements (DC events) as they occurred, while the physical time scale model fails to do so. Hence, it is clear that the DCRL can better sample the price changes than the physical time scale.

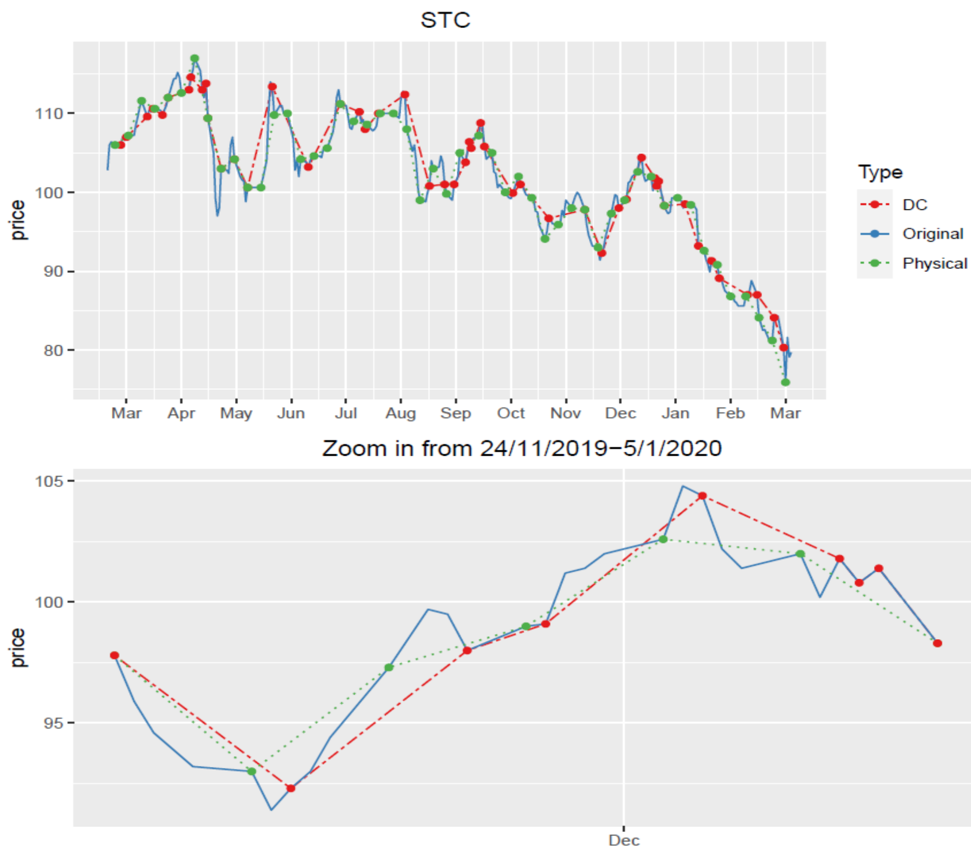

Fig. 4. The Price Curve Lines for STC Index using DC and Physical Time Compared to the Original Price Curve.

Table V compares the price-curve coastline of the events identified by the DCRL model using dynamic thresholds (intrinsic time intervals) against physical time changes (fixed time intervals) over the period March 17, 2019, to March 13, 2020. Table V clearly shows that the DCRL price-curve coastline c(λ) is longer for all investigated stock indices relative to the physical time price-curve coastline c(*t*). The coastline of Alinma under the DCRL model (i.e., DC intrinsic time) is more than three times longer than the physical time coastline (0.70 is the length of the DCRL coastline, and 0.22 is the length of the physical coastline). This difference can be the result of the time series evolution being unstable with significant price transitions occurring more frequently (refer to Fig. 2 for Alinma price time series). In contrast, SABB price-curve coastline using the DCRL model is slightly longer than its physical coastline but was closest to the physical coastline when compared with other investigated stock indices (0.89 was the length of the DCRL coastline, and 0.49 was for the physical time coastline). This finding can be the result of the often-recurring price transition but with insignificant price transitions (refer to Fig. 2 for SABB price time series). The DCRL price-curve coastline for the other stock indices (Alrajhi and STC) is at least two times longer than the physical coastline.

To summarize, the DCRL model-identified events using the intrinsic time outperforms the identified price transitions using the physical time for all investigated stock indices.

The natural fluctuation in the price time series suggests the need for diversification of the analytical scope of identifying financial events in the price time series. The DCRL mitigates the discontinuous price flow of prices in a time series and captures the periodic price changes.

2) Random-Based DC model: In this section, we further investigate the role and accuracy of the developed DCRL model in improving the decision-making process for the most appropriate dynamic threshold definition method. Therefore, we developed a random-based DC model that randomly selects a dynamic threshold definition method (randomly decide on one of the three dynamic DC equations: DT_Overnight, DT_Previous, or DT. The developed random-based DC model replaces the role of RL in selecting the DC dynamic threshold definition method. In contrast, DCRL finds the most appropriate dynamic threshold definition method using the DCRL policy (π).

Table VI provides a comparison for the accumulated reward value gained by the DCRL model and the random-based DC model over the period of March 17, 2019, to March 13, 2020. Evidently, the DCRL model outperformed the random-based DC model for all investigated stock indices, leading to the conclusion that the learning process of price movements (that is, upward and downward DC events) matters in the estimation of financial events in stock markets. The DCRL had proven to be effective in maximizing the accumulated value of the reward and, hence, the profitability during a sequence of learning steps for identifying events in different stock indices.

TABLE V. PRICE-CURVE COASTLINE LENGTH DEFINED BY: (I) THE DCRL MODEL C(Λ) AGAINST (II) PHYSICAL TIME CHANGES C(T) FROM 17/3/ 2019-13/3/2020. THE NUMBER OF DC EVENTS IS DENOTED BY NDC, AND PTI REPRESENTS THE PHYSICAL TIME FIXED INTERVAL

Index	N_{DC}	*c(λ)*	**PTI**	*c(t)*
Alrajhi	49	1.47	5.3 days	0.69
Alinma	45	0.70	5.8 days	0.22
SABB	57	0.89	4.5 days	0.49
STC	49	3.06	5.3 days	1.35

TABLE VI. ACCUMULATED REWARD VALUE GAINED BY THE DCRL AND RANDOM-BASED DC MODELS

Index	**DCLR**	**Random**
Alrajhi	2.21	1.82
Alinma	3.90	3.25
SABB	3.44	2.78
STC	2.64	2.09

V. CONCLUSION

In this paper, the DC event and RL approaches were used for automated pattern recognition from price time series. We proposed an intelligent intrinsic time-driven DCRL joint model, which can (1) adaptively set the DC dynamic threshold and conduct an event-based time series analysis using the RL approach, hence, improving the effectiveness, adaptability, and interpretability of the identified financial events; (2) jointly construct a price time series using the DC event approach, thus acquiring periodic continuous price events and improving the accuracy of the price time series representation. The DCRL is suitable for markets that operate during specific opening and closing times and can identify financial events without the need for an additional data source.

The effectiveness of the DCRL model is validated on the Saudi stock market with different price trends and patterns. The experimental results demonstrate that the DCRL model outperforms other physical time-based analyses and the random-based DC model with higher rewards and a more reliable representation of the price curves.

This work can be further extended and improved in future research directions. One direction can be conducting experiments on large-scale data, such as high frequency time series data, to confirm the effectiveness of and further enhance the DCRL model. Another promising research direction is to further apply the DCRL model to emerging markets, such as the cryptocurrency market. In addition, algorithmic trading can be developed using the DCRL model to trade one asset at a time and then can be improved and expanded to manage the portfolios of several assets. Finally, some financial features could be introduced to enhance the DCRL model; for example, trade volume could provide significant information for selecting the dynamic threshold.

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Constrained Quantum Optimization for Resource Distribution Management

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***Abstract*—The cloud computing field suffers from the heavy processing caused by the exponentially increasing data traffic. Therefore, optimizing the network performance and achieving a better quality of service (QoS) became a central goal. In cloud computing, the problem of energy consumption of resource distribution management system (RDMS) is presented as an optimization problem. Most of the existing classical optimization approaches, such as heuristic and metaheuristic have high computational complexity. In this work, we proposed a quantum optimization strategy that executes the tasks exponentially faster and with high accuracy named constrained quantum optimization algorithm (CQOA). We exploit the CQOA in RDMS as a toy example for pointing out the efficiency of the proposed quantum strategy in reducing energy consumption and computational complexity. Following that, we investigate the CQOA's implementation, setup, and computational complexity. Finally, we create a simulation environment to evaluate the efficiency of the suggested implemented constrained quantum strategy.**

Keywords—Quantum computing; constrained quantum optimization algorithm; quantum extreme values searching algorithm; resource distribution management; cloud computing

I. Introduction

Parameter optimization and the choice of the best solution candidate play a crucial factor in gaining optimal performance in many application types in a wide range of disciplines. It is useful to mention that most of the computational problems arising from the practical optimization world are frequently mapped to searching the minimum or maximum of a goal function (or a constraint goal function).

The cloud computing industry is suffering from intensive processing due to rapidly rising data traffic. As a result, improving the network speed and attaining a higher quality of service (QoS) became a top priority. In the last decades, several well-known quantum strategies have been proposed in quantum computing [1,2] such as quantum phase estimation (QPE) which is exponentially faster than the classical ones, it computes the eigenvalue of a unitary operator, it has many useful applications, here we list some examples, such as, quantum counting algorithm for computing the number of occurrences of a query (searched item) in a certain database, Shor's algorithm for integer factorization [3], or the HHL algorithm [4] for solving a linear system of equations. Another interesting well-known searching algorithm, the so-called Grover's algorithm (quantum solution for searching an item in an unsorted database) which enables a dramatic reduction in computational complexity. The optimal classical solution takes $O(N)$ iterations to carry out the search while Grover's strategy requires only $O(\sqrt{N})$ step [5-6].

In this work, we exploited the constrained quantum optimization algorithm (CQOA) [17]-[20] for optimizing the energy consumption of a proposed resource distribution management system (RDMS). It is important to mention that one of the motivations behind exploiting the CQOA in RDMS is that most of the constrained classical searching strategies suffer from high computational complexity for one of the following reasons,

- Most of the databases are Unsorted (unordered).
- The database may contain many local extremes (minimum or maximum) gratifying the constraint.
- The database structure is not always continuous.

The outline of this paper is as follows: Section II presents the literature review. Section III is devoted to introducing the CQOA and its computational complexity as well as showing a comparison between the CQOA and its original quantum algorithm version, the so-called quantum extreme value searching algorithm (QEVSA). Section IV deals with describing the resource distribution management model and the problem statement. Section V is concerned with implementing and configuring the proposed constrained quantum optimization approach in the desired resource distribution management. Section VI is devoted to discussing the computational complexity of the applied CQOA. Section VII presents the simulation results, and Section VIII concludes the paper.

II. Related Work

It is not easy to build a new efficient quantum algorithm that outperforms a classical one. For this sake, there are few discovered quantum algorithms. Concerning the constrained extreme value searching, the most leading quantum heuristic candidate is introduced in [7], the so-called quantum approximate optimization algorithm (QAOA) which approximates hard optimization problems by converting the classical objective function into a Hamiltonian problem. Later, the QAOA was exploited for solving a constrained optimization problem, this alternative solution investigates the ground state of the Hamiltonian cost function instead of minimizing the original cost function [8]. Another extended version of the QAOA, the so-called quantum alternating operator ansatz is designed for finding the approximate solutions to optimization problems with hard constraints [9].

The only drawback is that the calculation of the derivatives of the goal function can be computationally expensive. On the other hand, several well-known classical approaches for handling the constrained optimization search have been proposed in the literature, the most applied ones namely deterministic optimization algorithms and metaheuristic ones, these strategies are often failing to find the global optimum result when the goal function is non-monotonic, non-continuous, or the database is unsorted and very large [10]-[16].

It is worth showing the motivation behind applying the CQOA in RDMS. As it is known, new technologies continue to merge in cloud computing to meet the challenges imposed by the exponentially increasing data traffic [21]-[55]. Recent works [56-58], of the cloud radio access network, have shown significant performance gains by centralizing the management of radio and processing resources in the cost of computational complexity.

Due to the significance of the issues that the cloud environment addresses, many optimization methods have been proposed lately. The majority of them strive for a high quality of service.

The authors in [21] employed a hybrid prediction model that merges both statistical and machine learning approaches to generate higher-quality prediction outcomes for cloud computing. The proposed approach was able to predict with high accuracy the necessary workload. However, these techniques suffer from high computational complexity due to complex and highly nonlinear data. The model has been exploited to predict both seasonality and random workload patterns.

The authors in [22] proposed a hybrid technique with a shuffled leapfrog algorithm and ubiquitous binary search (SLFA-UBS) to resolve these issues with an optimal assignment and better resource distribution. The method performed better in terms of optimum dynamic resource provisioning with QoS and cheap cost.

Several metaheuristic approaches have been applied to improve the quality of service of cloud computing. For example, the authors in [26] suggested a multi-objective hybrid Ant Colony Optimization (ACO) with Bacterial Foraging (ACOBF) behavior to maximize resource utilization and also minimize the Makespan. While, the authors in [36] proposed another multi-objective hybrid method that combines the two well-known strategies, particle swarm optimization (PSO), and grey wolf optimization (GWO). The experimental outcomes proved that the newly developed method reduces the total execution time and cost compared to PSO, heterogeneous earliest time first (HEFT), ant colony optimization (ACO), and round-robin (RR) algorithms.

The author in [59] considered a cloud radio access network and aimed to minimize the energy consumption of the overall system while satisfying constraint demands. Moreover, the work in [60] executed sequentially two heuristic approaches for minimizing the power consumption of task processing. In addition, the author in [61] used the Matroid algorithm to optimally solve the constrained resource allocation problem. Another classical technique that is often used is the so-called knapsack optimization strategy which is widely investigated in the processing resource assignment in a cloud radio access network system [62-64]. However, the proposed optimization algorithms for task allocation require high computational complexity.

III. Constrained Quantum Optimization Algorithm

Before introducing the CQOA, let's present first the QEVSA. In [65]-[66] the author built a new quantum algorithm named quantum existence testing (QET) which is a special case of quantum counting algorithm that determines the number of occurrences M of a certain item in a database consisting of N entries [67]. While the QET tests whether a given entry exists or not in a certain database, in other words, it checks the value of M, if it equals zero or not. Next, the author developed a new quantum method called the quantum extreme value searching algorithm (QEVSA) by combining the well-known classical binary searching algorithm [68] and the QET. More details are presented in [65]-[66]. The QEVSA finds the extreme (minimum or maximum) of an unconstrained goal function or unsorted database.

The computational complexity (CC) of the QEVSA depends on,

- The CC of the binary searching algorithm embedded in the QEVSA which equals $O(log_2(T))$, where T is the maximum number of steps needed to run the logarithmic search.
- And, the CC of the QET which equals $O\left(log_2{}^3\left(\sqrt{N}\right)\right)$, where $N = 2^a$ is the entry size of the database, where a is the total number of the required qubits with respect to the size N of the database.

The overall number of bits n_E used in the physical implementation of the QET is strongly influenced by the quantum uncertainty and the classical accuracy of the application. In case the quantum uncertainty demand is neglected i.e. it corresponds to the idealistic phase estimation with no error, this implies that the value of n_E can be written as.

$$n_E = \underbrace{\frac{a}{2} - 1}_{c_E} \tag{1}$$

where c_E is the optimum number of qubits required for classical accuracy in order to represent the phase, in this case, the CC of the QET is $O\left(log_2{}^3\left(\sqrt{N}\right)\right)$. On the other hand, if the upper bound of the error probability is denoted by $\breve{P_\varepsilon}$ of the quantum uncertainty _originated from the QPE_ is taken into consideration by the application, then the value of n_E is expressed as.

$$n_E = \underbrace{\frac{a}{2} - 1}_{c_E} + \underbrace{\left\lceil log_2(2\pi) + log_2\left(\frac{1}{8\breve{P_\varepsilon}}\right)\right\rceil}_{p_E} \tag{2}$$

where p_E is the optimum number of qubits needed to handle the quantum uncertainty problem originating from the error probability of converting the phase to a probability amplitude. In this respect, the CC of the QET is $O\left(log_2{}^3\left(2^{\frac{p_E}{2}}\sqrt{N}\right)\right)$. We assume that the CC of the QEVSA is only influenced by the classical certainty parameter. For this sake, the CC can be written as $O\left(log_2(T)log_2{}^3(\sqrt{N})\right)$.

In compliance with what has been discussed, we see that the QET plays a fundamental role in the search efficiency of the QEVSA.

In [17]-[18], we developed a new extended version of the QEVSA, the so called CQOA, where we extended the functionalities of the QET(*ref*) to a new quantum function that answers whether there exists an item in a certain region of the database at all, and satisfies the engineering constraint *C* and index relation *R* (The value of *R* may refer to minimization or maximization of the constraint goal function) is needed. This new extended version is named the constrained quantum relation testing $CQRT(ref, R, C)$ where the parameter *ref* refers to the updated value which divides the database into two vertical parts, the index *R* refers to the used relation, and the constraint *C* can be equality or inequality constraint.

Also, we proved that implementing the constraint *C* and the relation *R* in the QET does not change the evaluation of QPE. For this sake, the estimated optimum number of qubits required for the classical accuracy denoted by c_R which corresponds to the CQRT function equals the c_E belonging to QET function, one obtains $n_R = n_E$. To this end, the computational complexity of the QEVSA equals the computational complexity of CQOA which equals $O\left(log_2(T)log_2{}^3(\sqrt{N})\right)$.

Note that the notation of *ref* value in the algorithm has been changed to $F_{med\,S}$. The CQOA is expressed as follows,

1) We start with S = 0 : $F_{min\,1} = F_{min\,0}$, $F_{max\,1} = F_{max\,0}$, and $\Delta F = F_{max\,0} - F_{min\,0}$

2) $S = S + 1$

3) $F_{med\,S} = F_{min\,S} + \left[\frac{F_{max\,S} - F_{min\,S}}{2}\right]$

4) $flag = CQET\left(F_{med\,S}, R, C\right)$:

- if $flag = Yes,$ then $F_{max\,S+1} = F_{med\,S}$
- Else $F_{max\,S+1} = F_{max\,S}$, $F_{min\,S+1} = F_{med\,S}$

5) If $S < log_2\,(T)$, then go to 2, else stop and $y_{opt} = F_{med\,S}$

It is important to mention that the QEVSA performs only the search in the continuous database structure because the QET cannot adjust the classical logarithmic search algorithm (binary searching algorithm) so that it is suitable for non-continuous databases.

The CQRT allows adapting the binary searching algorithm so that it is suitable for continuous database structures to non-continuous ones. To this end, the CQOA handles the search in a continuous or non-continuous database structure. The main similarities and differences between the QEVSA and CQOA are summarized in Table I.

TABLE I. THE MAIN SIMILARITIES AND DIFFERENCES BETWEEN THE QEVSA AND CQOA

	QEVSA	**CQOA**
Type of the goal function	Unconstraint goal function	Constraint goal function
Database type (Continuous/Non-Continuous)	Continuous	Continuous/Non-Continuous
The classical logarithmic search algorithm is combined with	QET	CQRT
Computational complexity	$O\left(log_2(T)log_2{}^3(\sqrt{N})\right)$	$O\left(log_2(T)log_2{}^3(\sqrt{N})\right)$
Database Structure (ordered/unordered)	Unordered database	Unordered database

IV. MODEL

This paper is an extension of the previous work published in [69-73], the of the current paper is reducing the energy consumption of processing resources by taking into consideration the delay constraint of the tasks. To model the general RDMS, we divided its functionalities into three main blocks. Fig. 1 represents the architecture of the proposed RDMS.

A. Multiple Task Generators

We consider multiple task generators, where each generator releases a task type to be served by computing units. We assume that the number of generators/task-types is denoted by *G*. Each generated task is composed of several subtasks selected from a set of subtask types, where the total number of different subtask types is V.

Each generator always produces identical tasks i.e. the same number of the total subtasks and the same number of subtask types. Moreover, each generator releases tasks according to an arrival time distribution (exponential intensity distribution, uniform intensity distribution, etc.). Note that, the memory needed to allocate the subtask type v is denoted by Δ_v. Furthermore, each task type has to be served within a specific delay constraint denoted by τ_g i.e. the subtasks belonging to task type g have the same *time constraint* τ_g i.e. all the subtasks of the task type g have to be served within this time constraint τ_g.

1) Computing units: The incoming tasks are served by computing units. The total number of computing units is denoted by *K*. Each computing unit has a maximum capacity c_k. Assuming that N_{vk} refers to the number of subtask type v under process on the k^{th} computing unit.

2) Decision maker: It controls the deployment of the incoming subtasks among computing units. The CQOA introduced in Section II will be implemented as a computational infrastructure core of the decision-maker.

B. Problem Statement

The decision-maker deploys the subtasks of the incoming task to different computing units. Assuming that the subtasks of the incoming tasks are processed sequentially. Fig. 2

illustrates the processing mechanism of subtasks in the k^{th} computing unit, where subtasks arrive in a FIFO manner, i.e. when a task arrives in the decision-maker, it decides instantly whether the task (consisting of subtasks) can be accepted and deployed to any of the computing units or not (rejected). The delay needed to process the actual load in the k^{th} computing unit (considering the task under the decision, too) denoted by τ_k^{act}, it has to be always less or equal than the delay constraint of the incoming task type i.e. $\tau_k^{act} \leq \tau_g$. The green hatched subtask is the subtask belonging to the new incoming task deployed into the k^{th} computing unit (see Fig. 2). This decision method guarantees that the delay constraint of tasks that are running on the k^{th} computing unit does not influence the fulfillment of delay constraint of the new incoming task and vice versa.

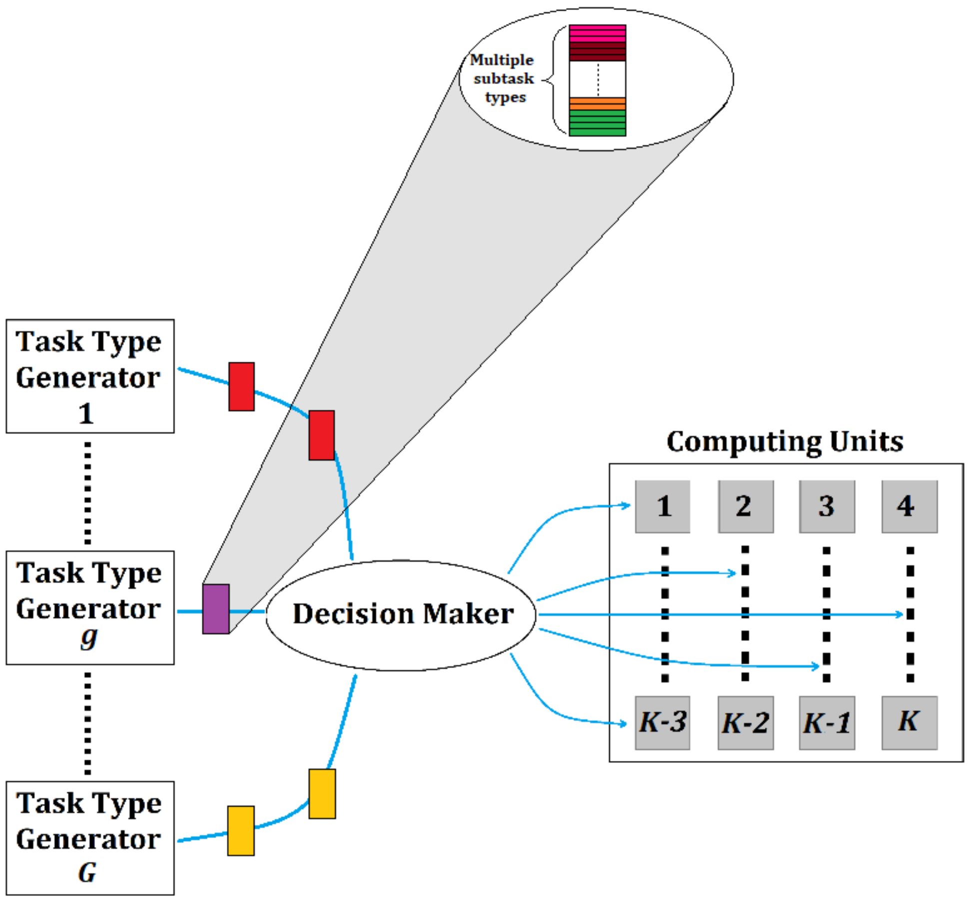


Fig. 1. Resource Distribution Management System.

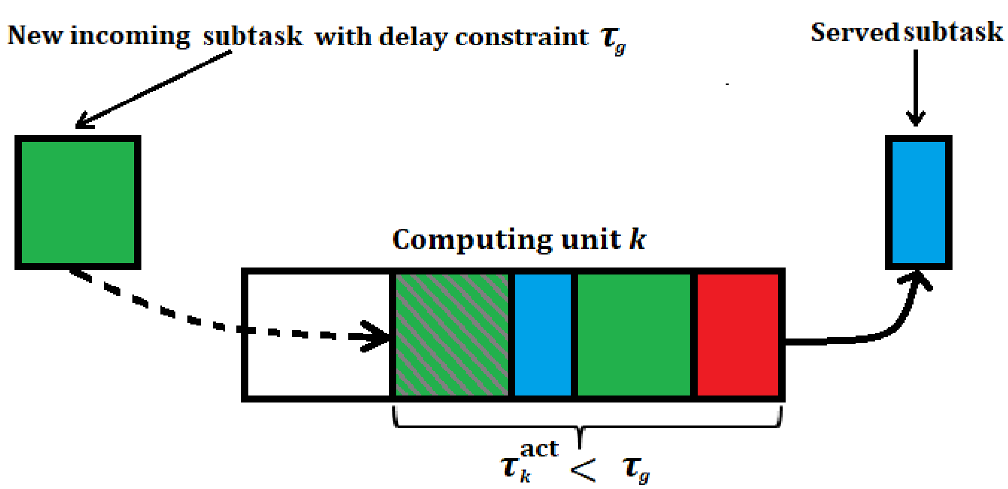


Fig. 2. Scheme Illustrating the Sequential Processing Operation of different Subtasks in the k^{th} Computing Unit.

Now, let's investigate the calculation of the total energy consumed by the RDMS. We consider that the initial power needed to turn on the computing unit k is denoted by P_k^{init}.

A subtask is composed of a specified number of identical memory pieces called *memory units*. The processing rate of the k^{th} computing unit is denoted by β_k and computed as follows,

$$\beta_k = \frac{number\ of\ memory\ units}{second} \quad (3)$$

On the other hand, the time needed to process a subtask type v on the computing unit k is Δ_v/β_k. Furthermore, the processing delay of the actual load on the k^{th} computing unit can be calculated as,

$$\tau_k^{act} = \frac{\sum_{v=1}^{V} N_{kv}\Delta_v}{\beta_k} \quad (4)$$

Assuming that $\tau_k^{act} \leq \tau_g$ and the processing of the subtasks is performed sequentially as illustrated in Fig. 2, the energy required to process the subtasks on computing unit k is given by formula (5), where ε_k is the energy consumption of one memory unit on computing unit k.

$$\begin{aligned} E_k^{act} &= \varepsilon_k \sum_{v=1}^{V} N_{kv}\Delta_v + P_k^{init}\tau_k^{act} \\ &= \left(\varepsilon_k + \frac{P_k^{init}}{\beta_k}\right)\sum_{v=1}^{V} N_{kv}\Delta_v, \end{aligned} \quad (5)$$

- $\varepsilon_k \sum_{v=1}^{V} N_{kv}\Delta_v$: The energy needed to serve the subtasks under process on the computing unit k without considering the energy required to turn on the computing unit k.
- $P_k^{init}\tau_k^{act}$: The energy needed to turn on the computing unit k in a period that is equal to τ_k^{act} (the energy of tasks is not considered).

It is straightforward to verify that the overall energy consumption of the system can be written as,

$$\begin{aligned} E^{act} &= \sum_{k=1}^{K} E_k^{act} \\ &= \sum_{k=1}^{K}\left(\varepsilon_k + \left.\frac{P_k^{init}}{\beta_k}\right|_{k\in H^{on}}\right)\sum_{v=1}^{V} N_{kv}\Delta_v. \end{aligned} \quad (6)$$

where the term $\frac{P_k^{init}}{\beta_k}$ is considered if and only if the k^{th} computing unit is switched on (The set H^{ON} of the switched-ON computing units). Our goal is to minimize the overall energy consumption E^{act}, one obtains.

$$E_{min}^{act} = \min_{\forall S_i \in S} E^{act}(S_i)\ and\ \forall k \in S_i : \tau_k^{act} \leq \tau_g \quad (7)$$

with S denotes the sets of different possible distributions of the subtasks of the incoming task among all computing units and S_i refers to the i^{th} distribution/deployment scenario of S, i.e. the i^{th} specific set of computing units $S_i = \{k\}$.

V. Implementation and Configuration of the CQOA

To select the best and the optimum deployment scenario, we apply the CQOA as a minimum constrained searching algorithm (MCSA). To this end, the function F is substituted by E^{act}, while the constraint C corresponds to the delay constraint of the incoming task type i.e. τ_g, and the implemented relation R is a "minimization".

The maximum number of steps needed to run the logarithm search T in (8) depends on two parameters: the variation of the energy consumption of the system denoted by $\Delta E = E_{max}^{act} - E_{min}^{act}$ and the step size α which is the smallest distance between the energies of two different scenarios among all the possible scenarios in the database. Fig. 3 shows these parameters.

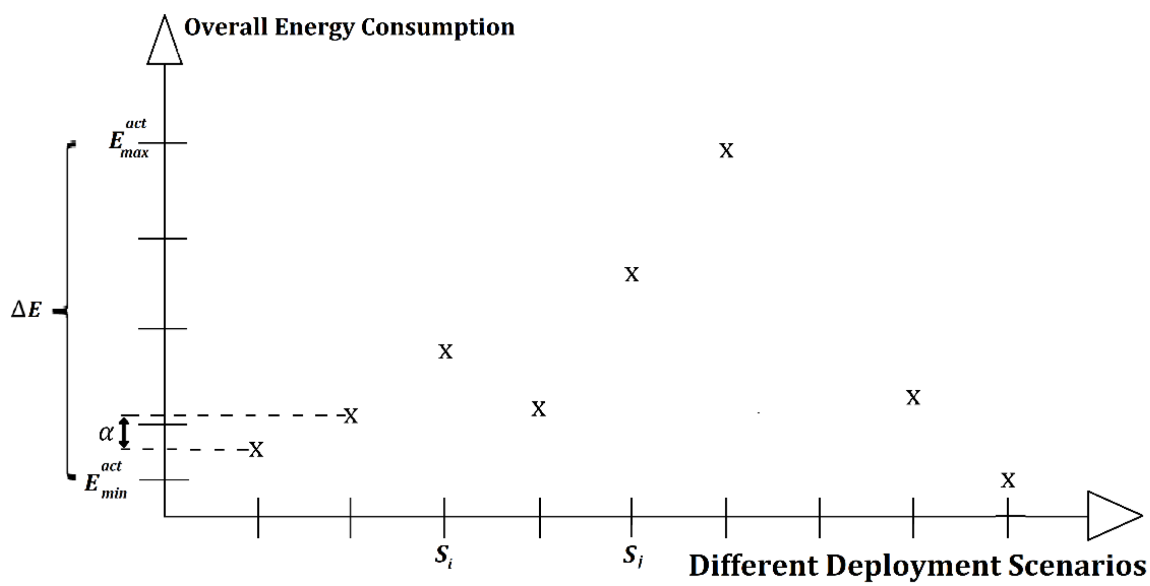


Fig. 3. The Horizontal Axis Presents all the Possible Deployment Scenarios, While the Vertical Axis Presents the Borders of the Total Energy Consumption Function (different Results), each Possible Scenario Corresponds to a Total Energy Consumption. Computing the Value of α Requires Selecting the Minimum Distance between Total Energy Consumption Functions of Two Deployment Scenarios S_i and S_j.

Since the searching region is obviously $\Delta E = E_{max}^{act} - E_{min}^{act}$, the stochastic parameter T can be expressed as follows.

$$T = \frac{E_{max}^{act} - E_{min}^{act}}{\alpha} \quad (8)$$

where E_{min}^{act} can be replaced by the energy consumption of the system without the new incoming task. We denote this energy value by $\breve{E}^{act}$ and one can observe that it does not depend on the deployment of the incoming task, this implies that.

$$T = \frac{E_{max}^{act} - \breve{E}^{act}}{\alpha} \quad (9)$$

An appropriate worst-case estimation for E_{max}^{act} can be considered as.

$$E_{max}^{act} = \breve{E}^{act} + \tau_g \sum_{k \in H^{OFF}} P_k^{init} + E_{max}^{inc}. \quad (10)$$

where,

- E_{max}^{inc} denotes the energy consumption if the subtasks of the incoming task are deployed onto that computing units having the largest ε_k , i.e., the least energy-efficient unit.

$\tau_g \sum_{k \in H^{OFF}} P_k^{init}$ is the total energy consumed by the set H^{OFF} of the switched-OFF computing units because the switched-ON computing units are already considered in $\breve{E}^{act}$.

On the other hand, the value of α can be written as,

$$\alpha = min_{\forall\, i \neq j} \left| E^{act}(S_i) - E^{act}(S_j) \right| \quad (11)$$

where $E^{act}(S_i)$ is the sum of the energy consumption of the system without the new task $\breve{E}^{act}$ and the energy consumption of the incoming task with assuming that it was distributed according to Z_i,

$$E^{act}(S_i) = \breve{E}^{act} + E^{inc}(Z_i). \quad (12)$$

where Z_i refers to the i^{th} set of those computing units which receive one or more subtasks of the new incoming task. It is straightforward to verify if one substitute (12) into (11), one obtains:

$$\alpha = min_{\forall\, i \neq j} \left| E^{inc}(Z_i) - E^{inc}(Z_j) \right| \quad (13)$$

Let M_{kvi} be the number of subtasks of the incoming task from subtask type v deployed onto computing unit k in case of the i^{th} deployment scenario. The formula of $E^{inc}(Z_i)$ can be expressed now by means of (14) as:

$$E^{inc}(Z_i) = \sum_{k \in Z_i} \left(\varepsilon_k + \left. \frac{P_k^{init}}{\beta_k} \right|_{k \in H^{on}} \right) \sum_{v=1}^{V} M_{kvi} \Delta_v \quad (14)$$

where this term $\frac{P_k^{init}}{\beta_k}$ is considered if and only if the k^{th} computing unit is switched-ON. To set up properly the stochastic parameter α, it is enough to investigate the non-zero solutions of $\left(E^{inc}(Z_i) - E^{inc}(Z_j) \right)^2 = 0$, the solutions are located on a hyper-plane, this result is already discussed in [73].

VI. Computational Complexity Analysis

As previously presented, in order to minimize the constrained overall energy consumption, we have exploited the CMSA as a computational infrastructure for the RDMS. Furthermore, we have proven that the computational complexity of the implemented CQOA is $O\left(log_2(T) log_2{}^3\left(\sqrt{N}\right)\right)$, it depends on the computational complexity of the CQRT function $log_2{}^3\left(\sqrt{N}\right)$ and the logarithmic search of the quantum algorithm $log_2(T)$, where N refers to the total number of possible deployment scenarios.

The computational complexity analysis is divided into two main parts,

- The value of T roughly depends on the value of the stochastic parameter α. As already investigated in [73], computing repeatedly the value of α poses a real challenge. To this end, we proposed an alternative solution that consists of setting up the T value in advance before starting the assignment operation, in this case, the computational complexity of determining the parameter α of the logarithm search will be $O(1)$. More details on the computational complexity of T are presented in [73].
- The size of the search space N. This section will be devoted to estimating the value of N which refers to the set of all possible assignment scenarios for each incoming task.

Let us assume that the new task under decision has arrived from generator g. This task contains M_{gv} identical subtasks from type v and we need to select M_{gv} pieces of computing units from the overall K where repetition is allowed, i.e. a certain computing unit can be chosen more than once. One can verify that the number of such possible different sets can be written as:

$$\binom{K + M_{gv} - 1}{M_{gv}} \quad (15)$$

Considering all the subtask types, one gets.

$$N = \prod_{v=1}^{V} \binom{K + M_{gv} - 1}{M_{gv}} \quad (16)$$

Now, we are ready to investigate the computational complexity of the lower and upper bounds of the size of search space N. It is easy to show that

$$\begin{aligned} \binom{K + M_{gv} - 1}{M_{gv}} &= \frac{\left(K + M_{gv} - 1\right)!}{(K-1)!\ M_{gv}!} \\ &= \frac{\left(K - 1 + M_{gv}\right)!}{(K-1)!\ M_{gv}!} \end{aligned} \quad (17)$$

Assuming that $K \gg M_{gv}$, it is interesting to note that by using formula (17), one can verify that it can be expressed in the following manner:

$$K \frac{(K+1)\cdot(K+2)\cdot\ldots\cdot(K-1+M_{gv})}{1\cdot 2\cdot\ldots\cdot M_{gv}} = \frac{K}{M_{gv}} \prod_{i=1}^{M_{gv}-1} \left(\frac{K}{i} + 1 \right) \quad (18)$$

Now we are in a position to give the upper bound for (16). Using (18), one can confirm that

$$\binom{K+M_{gv}-1}{M_{gv}} \leq \frac{K^{M_{gv}}}{min_v\, M_{gv}} \tag{19}$$

Using (19) and (16), the upper bound of the size of the search space N can be expressed as:

$$N = \prod_{v=1}^{V} \binom{K+M_{gv}-1}{M_{gv}} \leq \left(\frac{K^{M_{gv}}}{min_v\, M_{gv}}\right)^V \tag{20}$$

Next, we are interested in a close lower bound for (16). It is easy to verify that

$$N \geq \left(\frac{K^{M_{gv}}}{max_v\, M_{gv}!}\right)^V = \left(\frac{1}{max_v\, M_{gv}!}\right)^V K^{M_g} \tag{21}$$

where, $M_g = \sum_{v=1}^{W} M_{gv}$.

The lower bound expressed in (21) shows that the computational complexity of finding the optimal solution within the database is polynomial in terms of the numbers of computing unit K but exponential in terms of M_{gv}, i.e. if the number of subtask type V becomes large, the computational complexity rises dramatically. For this sake, performing a constrained classical computation method to find the optimum result will be time-consuming and hard to solve. So, our proposed quantum strategy is the best candidate to handle such a task assignment optimization problem.

VII. Simulation

To demonstrate the efficiency of the proposed CQOA, a simulation environment has been constructed, in which a constrained randomized method was considered as a reference for comparison with the proposed constrained optimization method. In the best case, the computational complexity of the constrained randomized method is $O(const)$, and in the worst case, it is $O(N)$.

This simulation aims to compare the performance of both methods in terms of computational complexity and the overall energy consumption with respect to the delay constraint.

The simulation of the RDMS hosts three computing units, the characteristics of computing units are presented in Table. II, we considered three computing units where they have an identical processing rate of 40. From a practical point of view, the RDMS contains significantly more computing units, however, to observe the trends and effects it is worthwhile investigating a small-scale model.

Also, we considered two task type generators such that tasks are generated exponentially, where one of the task types has a high-intensity distribution (the mean value of intensity distribution is smaller) compared to the other one. Furthermore, we considered two subtask type, their memory requirements are respectively $\Delta_1 = 2$ and $\Delta_2 = 4$. Table III presents the number of subtask types, total memory required, and the delay constraint of each task type. While Table IV shows the total number of tasks released for each intensity distribution. It is important to mention that the timeslot of task generation is 20 seconds.

TABLE II. THE CHARACTERISTICS OF THE COMPUTING UNITS OF RESOURCE DISTRIBUTION MANAGEMENT MODEL

	Computing Unit 1	**Computing Unit 2**	**Computing Unit 3**
c_k	40	80	120
P_k^{init}	20	25	30
ε_k	1	2	3

TABLE III. THE CHARACTERISTICS OF THE GENERATED TASK TYPES

	Number of Subtask type 1	**Number of Subtask type 2**	**memory**	**Delay constraint**
Task type 1	1	3	14	1.4
Task type 2	3	1	10	1.2

TABLE IV. THE NUMBER OF TASKS RELEASED FOR EACH INTENSITY DISTRIBUTION

	Mean = 0.4	**Mean = 0.3**	**Mean = 0.2**	**Mean = 0.1**
Number of tasks	39	57	91	203

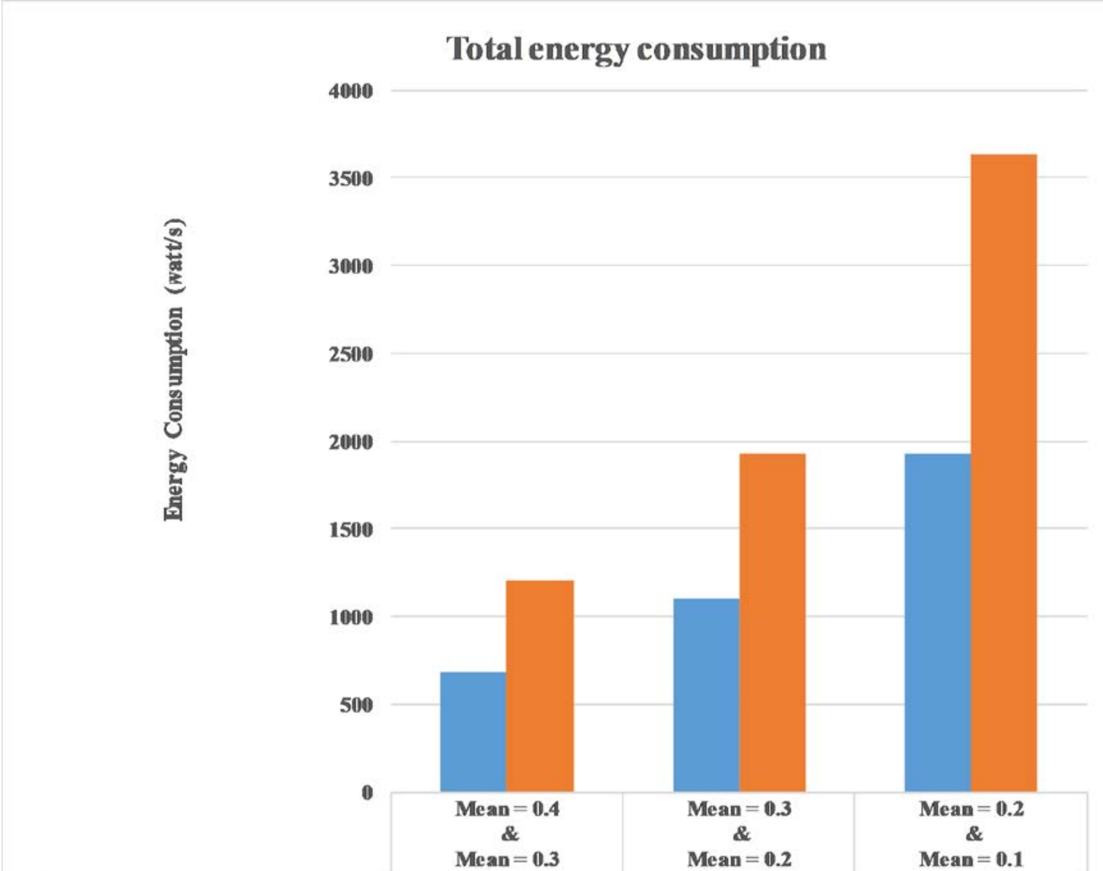
It is interesting to note that the decision-maker checks first the capacity constraint i.e. if there is free space in the system for allocating the new task. Then, it checks the delay constraint. Also, it is very important to mention that we did not deal with the case where the system is overloaded, i.e. we did not investigate the queueing behavior of the system.

For each two task types that have different intensity distributions, we repeat the simulation 10 times, then we calculate the average overall energy consumed for each algorithm.

Fig. 4 compares the total energy consumed by the randomized and optimized methods for different exponential intensity distributions. It can be seen that for every experiment, the constrained optimized strategy consumes less energy than the constrained randomized one. Additionally, one can notice that when the intensity distribution of arrival tasks increases i.e. when the mean value of exponential distribution becomes smaller, the optimized strategy keeps consuming lower than the randomized one.

Fig. 5 shows the percentages of the overall energy consumption reduction of the three aforementioned experiments. For example, in the first experiment where the two task type generators have respectively 0.4 and 0.3 as means (the mean value of exponential distribution), the energy consumption of the optimized method is less than the randomized one by approximately 43.85 %.

As it is shown, in the worst case the constrained randomized algorithm uses N steps, but it cannot find the optimum deployment scenarios which correspond to the minimum total energy consumption of the RDMS. While the computational complexity of the constrained optimized strategy is $O\left(log_2(T)log_2{}^3\left(\sqrt{N}\right)\right)$.



	Mean = 0.4 & Mean = 0.3	Mean = 0.3 & Mean = 0.2	Mean = 0.2 & Mean = 0.1
Constrained Optimized method	676.05	1103.35	1925
Constrained Randomized method	1204.025	1925	3636.468

Fig. 4. Energy Consumption of the Optimized (Blue Bars) and the Randomized (Red Bars) Strategies according to different Intensity Distributions.

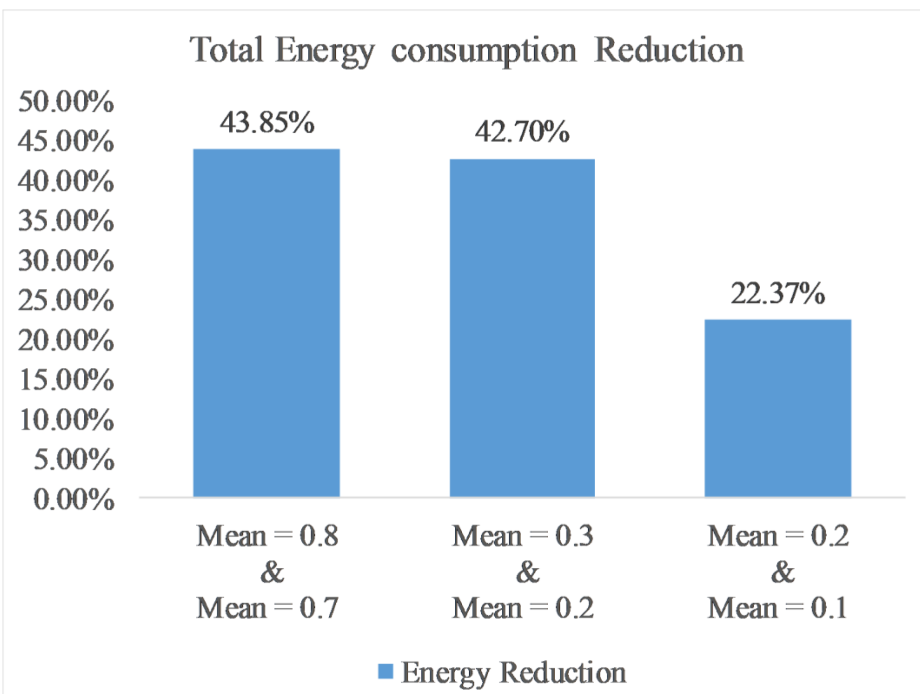


Fig. 5. Energy Consumption Reduction.

To sum up, we see that whatever the distribution intensity is, the constrained optimized approach offers a significant reduction in terms of energy consumption and computational complexity.

VIII. Conclusion

The CQOA finds the extreme optimum value for a constraint goal function or unsorted database with respect to certain constraints. It reduces significantly the costs connected to the application such as computational complexity and time, as well as, provides high accuracy and speed. We exploited the CQOA to minimize the constraint goal function (The total energy consumption) of the RDMS. We derived a simplified form of the constraint goal function, and we investigated the implementation and the configuration of the proposed constrained quantum strategy. Next, we proved that the computational complexity of finding the optimal solution within the database is polynomial in terms of the numbers of the computing units but exponential in terms of the number of subtasks. Fortunately, the proposed CQOA can handle such kind of optimization problem exponentially faster. In the end, we demonstrated by a simulation environment the effectiveness of the CQOA in terms of energy consumption and computational complexity by making a comparison between the constrained randomized strategy and the constrained quantum one. In future work, we will exploit the CQOA in resource distribution management by considering queueing aspect.

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Prototype Design and Experimental Evaluation e-Healthcare System based on Molecular Analysis Devices

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***Abstract*—Recently, wireless body area networks (WBANs) and mobile Internet of Things (IoT) have been greatly increased and integrated into a different type of systems such as electronic/mobile-healthcare (e/m-healthcare) systems. In addition, analyzing the composition of drugs or performing the medical rapid tests in the conditions field are the main tasks of the m-healthcare system, in which the traditional laboratory methods of analysis are not suitable. Therefore, in this study, we proposed a novel structure with a distributed e-health system to perform such analysis, where portable infrared micro spectrometers are utilized and then boundary calculations are applied. More specifically, this system is proposed to use a portable infrared micro spectrometer with a specially designed application connected to a public communication network, which can process the results of analysis using boundary calculations. Moreover, it provides remote processing and long-term storage of analysis data using artificial neural networks and cloud technologies. Finally, simulation results show that preprocessing (error checking), data buffering and Edge Computing can significantly reduce the network latency and volume of transferred data.**

***Keywords*—Micro spectrometer; molecular analysis; NIR spectroscopy; public communication networks; internet of things; e-health; m-health; edge computing**

I. Introduction

The quality of medical services in the modern world depends very much on several important factors. Firstly, it is the time before medical care is provided, and the shorter the time, the better for the patient. The second factor is the level of automation and informatization of the process of providing medical care, because it eliminates the human factor and improves the quality of medical services. The third factor is to reduce dependence on existing infrastructure and to provide medical care at any time and in any place. This factor significantly depends on the level of technology and telecommunications development [1].

When they talk about the integration of modern technology and medicine, the most commonly considered area of knowledge is e-Health (also written e-health). This is a field of knowledge that studies the tasks of digitalization of medical service delivery, development of new high-precision medical equipment, integration of medical systems with telecommunication technologies, implementation and application of robots and artificial intelligence (AI) in medicine [2, 3]. Today most countries in one way or another implement e-health system in everyday medical practice [4, 5, 6], the level of trust of patients and doctors in such systems is steadily increasing [7].

The concept of mobile e-health (m-health) has emerged due to the fact that tablets or smartphones have become the most common means of communication in today's world. It includes medical practice and public health carried out using mobile devices [8, 9]. Mobile e-health is developing very rapidly because it relies on the use of devices and technologies familiar to the average user, such as smartphones, tablets, smart watches, and the Internet. Importantly, m-health technologies allow patients to remain mobile and monitor their health status in their daily lives without significant limitations. On the other hand, m-health uses cloud platforms and Edge Computing [10, 11, 12] to accumulate data, process and store them, and perform deep analysis using AI.

m-Health technologies provide many different services. These include access to public health care sites for appointments or consultations, mobile applications for monitoring medication schedules or adherence to physical activity and daily routines [13], and various applications related to the collection and analysis of data from wearable sensors [14].

Some of the services that m-health provides are various methods for analyzing the composition of food and medicines [15, 16], noninvasive blood tests [17, 18, 19], and other medical tests that are based on the use of infrared spectroscopy [20, 21, 22].

Until recently, there were no devices whose technical characteristics would allow the use of infrared spectroscopy methods under "field" conditions. Such studies were previously carried out using bulky, expensive and complex equipment exclusively by highly qualified specialists. Fortunately, thanks to rapidly developing technology and an increasing level of production [23], a number of portable wearable spectrometers are now available that allow such analyses to be performed.

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These spectrometers implement the "Lab-On-A-Chip" (LoC) (or sometimes even "System-On-A-Chip" (SoC)) concept, which involves using a microchip to perform a complete biochemical analysis procedure, allowing one or more processes on one microchip using a minimum number of samples for the study [24].

An important point that determines the possibility of massive use is the cost of such devices. Of course, a device with a very high cost will not be as much in demand and widespread as one with a small cost. Today there are already examples of devices for spectrometric analysis with low cost and small size [25, 26].

The main contributions of this study are summarized as follows:

- Developed a prototype of the e-healthcare system based on molecular analysis devices for recognizing medicines in case of absence or damage to the labeling on the package.
- Implemented the interception and analysis of network traffic generated during the operation of the system was carried out and its characteristics.
- Proposed an algorithm to minimize network latency and volume of transferred data when using e-healthcare system based on molecular analysis devices.

The rest of the paper is organized as follows. Section 2 the related work. Our proposed a prototype system is presented in Section 3. Then, the Network traffic interception and characterization in Section 4. The proposed algorithm and simulation results in Sections 5 and 6. Finally, Section 7 concludes the paper.

II. Related Work

Here are a few examples of m-health devices or systems that use handheld spectrometers to analyze the composition of various substances.

For example, the authors of one paper describe the development of a smartphone-based system for accurate and reliable assessment of sulfate and chloride levels in the water. The developed system is based on the detection of the transmitted modulated signal (for spectrophotometric study) and the intensity of the scattered signal (for turbid metric study) of the liquid sample. The specially developed application allows to carry out the analysis autonomously and to display the results in a user-friendly format. The system proposed by the authors to study the composition of liquids can become a scalable platform, which after some modernization can be used to monitor other parameters of water or other liquids [27].

Another article presents a miniature and cost-effective spectrophotometer used for real-time biomarker detection. The prototype consists of a highly sensitive spectrometer embedded in a low-cost housing made using 3D printing technologies and a specially designed printed circuit board that provides processing and wireless data transmission. The results show that the portable system developed by the authors can identify the tubulin protein, which is a well-known biomarker used in diagnosing various types of cancer. The developed prototype has a small size and low power consumption [28].

One of the articles describes the using of a portable low-cost spectrophotometer for detecting nitrites in a liquid that simulate the urine of patients. This can be used in medical practice to determine the presence of a bacterial infection in the urinary tract. When developing the spectrophotometer, the authors used an ultraviolet LED of peak emission at 370 nm as a light source. A silicon pin photodiode was used as a detector of the reflected spectrum. A microcontroller was used as a platform for controlling the sensors. This spectrophotometer provides a real-time display of the result. To test the operation of the spectrophotometer, the results of its operation were compared with the results of the study using a dipstick test. In the future, the authors plan to conduct additional studies on real urine samples [29].

In another article, the authors describe a peripheral system based on the Raspberry Pi platform for processing data from the intensive care unit (ICU). The authors propose to process incoming data from medical equipment on the periphery of the network to unload the hospital's cloud platform. Medical data was modeled on the basis of the PhysioNet MIMIC III database and transferred to the edge platform for processing and detecting emergency cases. Then the data was transferred to the cloud level [30].

In another study, the authors developed a machine learning application to estimate the reflected electromagnetic spectrum in infrared spectroscopy. The use of artificial neural networks improved the recognition results compared to the previously used methods [31].

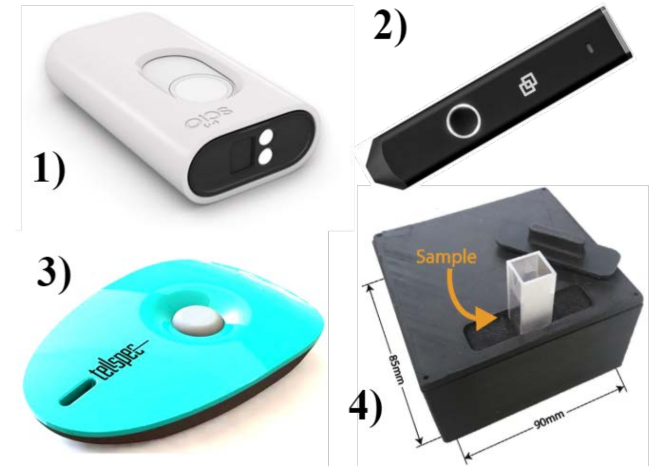
In another article, the authors review existing healthcare solutions and, as a result of their analysis, propose a new architecture for developing a dedicated e-health platform. It is assumed that such a platform will implement the Platform as a Service (PaaS) service delivery model and allow for faster development and implementation of specific medical services [10].

III. Developing a Prototype System

In this article, several handheld devices designed for infrared myrospectroscopy analysis were studied to develop a prototype m-health system. These devices are on free sale and already have a certain number of users. They are positioned by the developers as general purpose NIR spectrometers. The appearance of these spectrometers is shown in Fig. 1.

These devices are SCiO manufactured by Consumer Physics, LinkSquare manufactured by Stratio, Inc., Tellspec spectrometer manufactured by Tellspec, Inc. and a personal spectrometer developed on the basis of the open source project [26].

The devices interact with a smartphone, tablet or laptop during their operation in order to access the Internet in order to transfer data or to display the results in a user-friendly form. Let's look at the scanning process, which is about the same for these devices.



1) SCiO device, 2) LinkSquare device, 3) Tellspec device and 4) open source project

Fig. 1. Spectrometers considered in the Study.

During scanning, the infrared beam of the micro spectrometer falls on the object under study and is reflected. The energy absorption of the beam occurs at wavelengths whose energy corresponds to the excitation energies of the vibrations in the irradiated molecules. The reflected infrared beam with an altered spectrum hits the sensor of the micro spectrometer. Based on the reflected infrared spectrum, which is the wavelength dependence of the radiation intensity, the composition of the scanned substance is evaluated. Next, the data from the micro spectrometer is transmitted to a smartphone or tablet, where it is accumulated and preprocessed. After the preliminary analysis, the data from the user's smartphone is sent to a cloud server for further in-depth processing based on a database of reference spectra. The results of the analysis are transferred to the smartphone and displayed in the application in a user-friendly form.

In order to implement the m-health prototype system, an applet was developed for drug analysis using the LinkSquare NIR micro spectrometer and an AI-enabled cloud platform. The technical characteristics of the LinkSquare spectrometer are presented in Table I. The appearance of the LinkSquare spectrometer is shown in Fig. 2. The developed applet is a software module for the main application.

TABLE I. TECHNICAL CHARACTERISTICS OF THE LINKSQUARE NIR SPECTROMETER

Name	*Value*
Size (L x W x H)	114.0 x 23.9 x 23.9 mm
Weight	57g
Charging Time	< 1.5 hrs
Battery Life (Active)	~ 1000 scans
Battery Life (Idle)	24 hrs
Connectivity	Wi-Fi (802.11 b/g/n)
Wavelength	700nm - 1000nm
Data Points	600 points per scan

Fig. 2. LinkSquare NIR Spectrometer.

The developed applet should be able to recognize medicines sold in pharmacies without a prescription and issued in the form of tablets. The applet can be used by both ordinary users and medical professionals to recognize medicines in case of missing or damaged markings on the packaging, as well as to recognize counterfeit medicines.

To collect the data needed to train the neural network and create the applet, a specialized LS Collector application was installed on the laptop to collect spectrograms. The data collection in the LS Collector program is shown in Fig. 3. After that, spectrograms for different medicines were collected. The collected data was uploaded to the cloud platform to train the neural network and create an applet. Next the neural network was trained based on the collected spectrograms. The number of training iterations was 10 000.

Next, the developed applet was installed through the platform Google Play on a smart phone running the Android operating system, after which it was tested. The main technical characteristics of the LinkSquare application and the developed applet are presented in Table II.

The test consisted of scanning and recognizing a random sample of the drug. For this purpose, medicines were used in the form of tablets without packaging. The results were repeated many times and statistically processed. The probability of successful recognition was 93 percent.

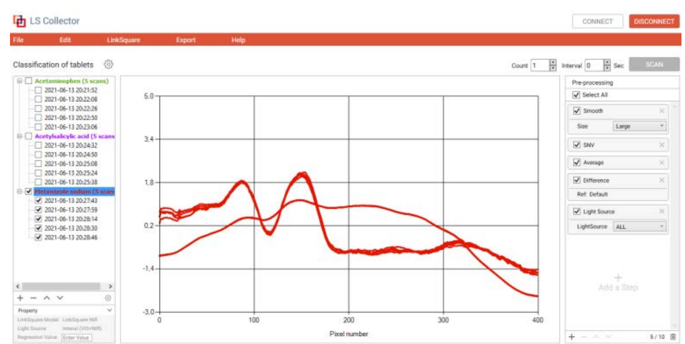
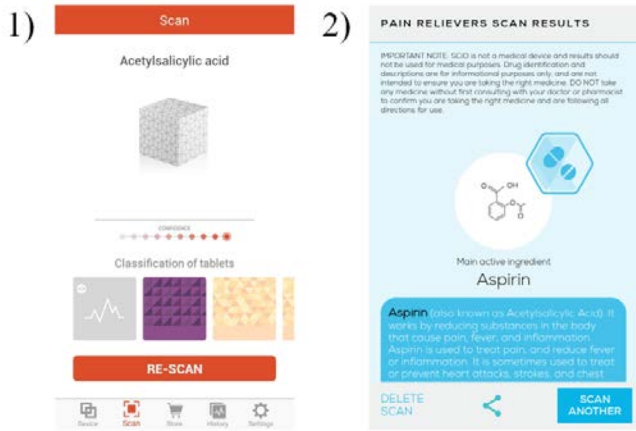


Fig. 3. Spectra samples Collection of various drugs for further processing

TABLE II. THE MAIN TECHNICAL CHARACTERISTICS OF THE LINKSQUARE APPLICATION AND THE DEVELOPED APPLET

Name	*Value*
Supported Platform	iOS 10.0 or above Android 5.0 or above
The size of the main LinkSquare application	94 Mb
The size of the developed applet	9 Mb
The number of iterations in the machine learning process	10 000
Probability of successful recognition	0,93

The Fig. 4 shows the result of the analysis and the appearance of the developed applet, as well as a comparison with a similar applet for the SCiO spectrometer.



(1) Developed Applet for LinkSquare, (2) Similar Applet for the SCiO Spectrometer.

Fig. 4. The appearance of the GUI of the created applet and the SCiO applet

Testing of the applet to verify its performance was carried out based on the developed m-health prototype system, the structure of which is presented in Fig. 5. The prototype simulates a scenario of micro spectrometer application in everyday life to analyze the composition of medicines.

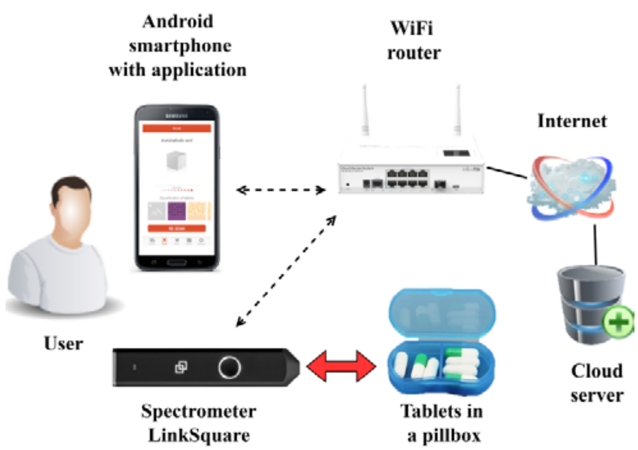


Fig. 5. Network Prototype.

IV. Network Traffic Interception and Characterization

The developed prototype was used to capture and analyze the IP network traffic generated by the m-health system. The traffic characteristics are presented in Table III.

The presented results were calculated with a confidence probability of 90%.

This is to assess traffic characteristics in detail and use them to further model the molecular analysis service delivery process using the m-health system. Such traffic and messaging algorithms may differ from those typical of the Internet [32], and a better understanding of the characteristics of m-health systems will solve existing problems and accelerate the development and diffusion of m-health in the future [33, 34].

TABLE III. Characteristics of the Network Traffic Generated during the Provision of the m-Health Service

Network traffic characteristics	***Sent by the spectrometer***	***Sent by the server***
The size of the sample (packets), n	5436	5510
The size of the sample (packets) per scan, n	34,3±0,57	29,05±1,05
Average packet length, bytes	1257,40±8,41	58,60±0,41
Packet receiving rate, packets/s	1,21±0,02	1,23±0,02
Packet receiving intensity, Kbit/s	11,87±0,22	0,56±0,22

To capture network traffic, the PCAP Remote mobile app was installed on the smartphone, which was used to capture and store network traffic. The traffic was then transferred to a laptop with WireShark traffic analyzer software for further study and evaluation of its characteristics.

In [12, 32], the following sequence of steps was described for an Internet-based real-time NIR spectrometer molecular analysis procedure, which is shown in Fig. 6.

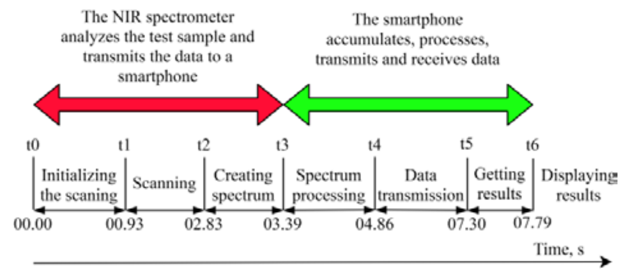


Fig. 6. The Sequence of Operations when using the m-Health System.

Obviously, in order to improve the quality of the m-health service, it is necessary to reduce the latency of the service. However, since we cannot influence the scanning speed of the spectrometer itself, we will further consider the delay associated with the accumulation, processing, transmission and reception of data by the smart phone.

V. Proposed Algorithm

After a detailed study of the operating principles and traffic analysis of m-health systems that use portable infrared micro spectrometers to analyze the composition of food and medicines, the following improved algorithm for the service was proposed. The algorithm is shown in Fig. 7.

A distinctive feature of this algorithm is the preprocessing of the data received from the spectrometer in order to compare it with a predetermined template. The template is selected depending on the applet used. The preprocessing allows you to discard data resulting from false positives and scanning errors. Thus, erroneous data is not transmitted over the Internet to a remote server for processing, which on the one hand reduces the amount of traffic transmitted, and on the other hand, discarding erroneous data allows the system to free up more quickly for the next scan.

Another distinctive feature is the presence of a buffer that accumulates data until its volume approaches the value of the maximum transmission unit (MTU), which reduces the number of transmitted packets and slightly increases the data transmission delay.

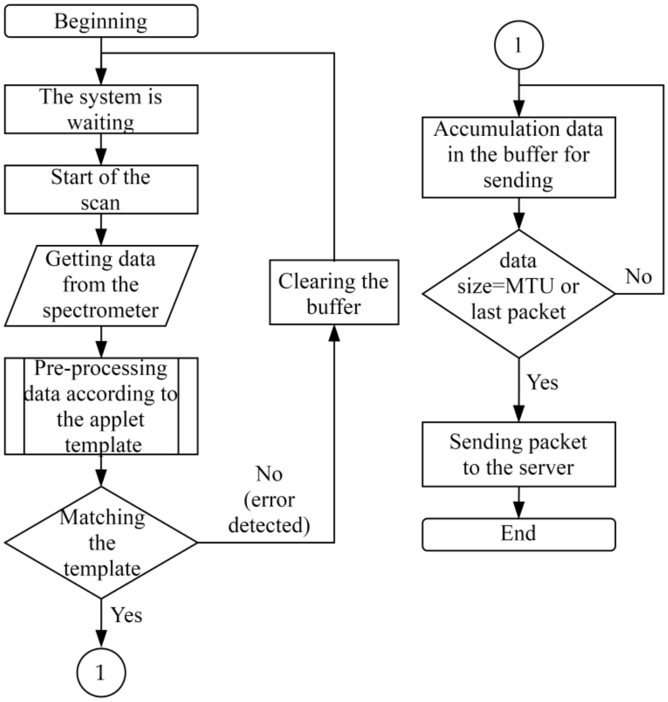


Fig. 7. Proposed Algorithm.

We should also consider the possibility of processing data not on a remote cloud server, but using Edge Computing technologies to reduce network latency and provide a higher level of m-health services [35, 36].

VI. Simulation Model

To verify the effectiveness of the above algorithm, a simulation models were developed in AnyLogic software. These models allows the simulation of both the basic scenario of service provision, as well as allows the simulation to take into account the features of the above-proposed algorithm and numerically assess the difference in the distribution of accumulation, processing and data transmission times in the process of providing m-health service using the NIR spectrometer and the volume of data transmitted for different scenarios. These are the basic scenario, the scenario with preprocessing (error checking), the scenario with buffering, and the scenario using Edge Computing.

The graph in Fig. 8 shows the distribution of the delay time associated with the accumulation, processing, transmission and reception of data in the basic scenario. It does not use any improvements, such as preprocessing (error checking) or Edge Computing. The simulation results are quite exactly the same as the results of the created network prototype.

The resulting distribution can be described with sufficient accuracy by an exponential distribution with a probability density

$$f_1(t) = \lambda e^{-\lambda t} \tag{1}$$

where λ is the intensity of service (served attempts).

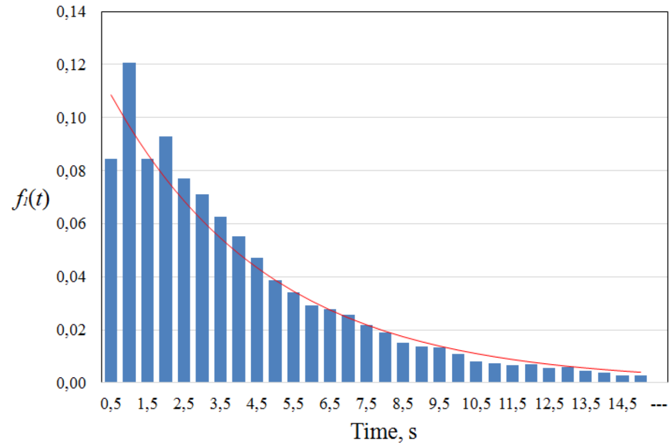


Fig. 8. Distribution of the Delay Time Associated with the Accumulation, Processing, Transmission and Reception of Data in the basic Scenario.

The graph in Fig. 9 shows the distribution of the delay time associated with the accumulation, processing, transmission and reception of data in a scenario with preprocessing (error checking). In this scenario, the delay reduction is achieved through preprocessing, which ensures that false scans are discarded even on the smart phone and the e-healthcare system is quickly released for subsequent work.

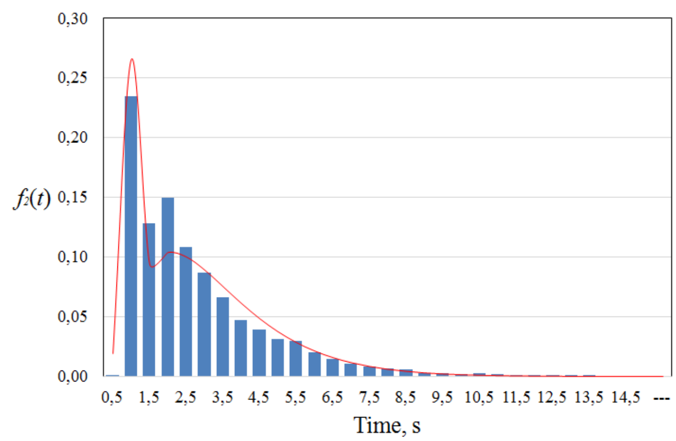


Fig. 9. Distribution of the Delay Time Associated with the Accumulation, Processing, Transmission and Reception of Data in the Scenario with Preprocessing (Error Checking).

This distribution is difficult to describe with a single function. We described it as a mixed distribution based on the assumption that this process can be represented as an aggregation of two independent processes. In this case, the probability density can be expressed as the weighted sum of the probability densities of two distributions.

$$f_2(t) = \eta_1 g_1(t) + \eta_2 g_2(t) \tag{2}$$

where η_1 and η_2 are weight coefficients, g_1 and g_2 are probability density functions (pdf).

$$g_1(t) = \eta_1 \delta(t) \tag{3}$$

where $\delta(t)$ – Dirac delta function.

$$g_2(t) = \begin{cases} \dfrac{t^{k-1}}{\theta^k \Gamma(k)} e^{-\frac{t}{\theta}}, & t \geq 0 \\ 0 & t < 0 \end{cases} \quad (4)$$

$g_2(t)$ – presents the Gamma distribution.

The graph in Fig. 10 shows the distribution of the delay time associated with the accumulation, processing, transmission and reception of data in a scenario with preprocessing (error checking), buffering and Edge Computing. In this scenario, the delay reduction is achieved through preprocessing, which ensures that false scans are discarded and the e-healthcare system is quickly released for subsequent work, as well as by processing data not on a remote cloud server, but using Edge Computing.

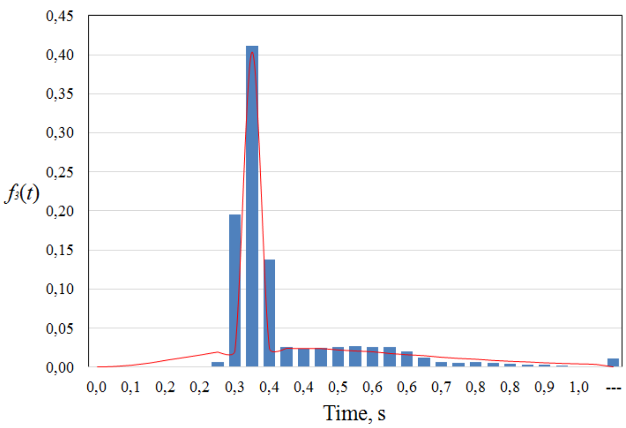


Fig. 10. Distribution of the Delay Time Associated with the Accumulation, Processing, Transmission and Reception of Data in the Scenario with Preprocessing (Error Checking) and Buffering and Edge Computing.

We described this distribution in a similar way using a mixed distribution with the difference that two Gamma distributions were chosen as terms.

$$f_3(t) = \eta_1 g_1(t) + \eta_2 g_2(t) \quad (5)$$

where η_1 and η_2 are weight coefficients, g_1 and g_2 are pdf functions.

$$g_2(t) = \begin{cases} \dfrac{t^{k-1}}{\theta^k \Gamma(k)} e^{-\frac{t}{\theta}}, & t \geq 0 \\ 0 & t < 0 \end{cases} \quad (6)$$

where $g_2(t)$ – presents the Gamma distribution.

Generalized results of modeling the distribution of time of service provision are presented in the Table IV.

The presented results were calculated with a confidence probability of 90%.

From the simulation results presented in Table IV, the use of preprocessing (error checking), buffering of data received from the spectrometer, and the use of Edge Computing for local data processing can significantly reduce the delay time associated with the accumulation, processing, transmission and reception of data.

TABLE IV. AVERAGE DELAY TIME

№	*Scenario type*	*Average service delivery time, s*
1	Basic scenario	4,354±3,923
2	Preprocessing (error checking)	2,543±1,860
3	Preprocessing (error checking) and buffering and Edge Computing	0,374±0,128

The graph in Fig. 11 shows the dependence of the amount of data transmitted in megabytes on the number of scans. As can be seen from the graph, the use of preprocessing (error checking) allows you to reduce the amount of data transmitted by discarding the spectra obtained as a result of erroneous or accidental (unintentional) scanning when using the e-healthcare system. Buffering reduces the number of transmitted IP packets, and therefore the amount of service information (headers), which reduces the total number of transmitted data.

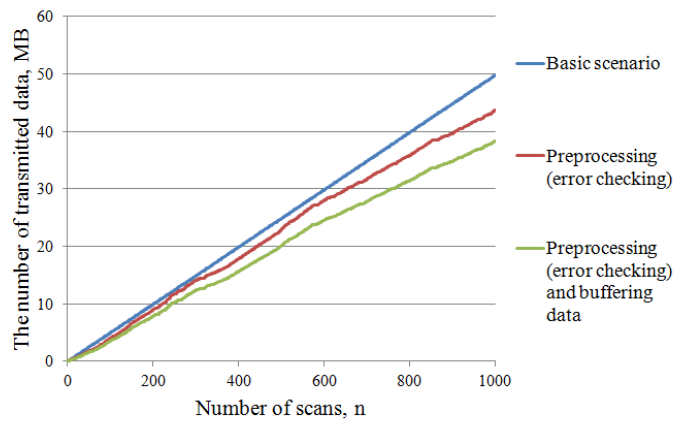


Fig. 11. Dependence of the Volume of Transmitted Data on the Number of Scans.

The resulting dependences can be described quite accurately by straight lines.

$$v(n) = a_i n \quad (7)$$

where a_i – is the corresponding slope ratio.

VII. CONCLUSION

In this paper, analyzes the use of infrared microspectrometers used for e-health and m-health systems and highlights the main promising areas of their use. In particular, m-health applet was developed using a cloud platform and AI, where this applet is designed to be installed on a smart phone or tablet under the Android operating system as part of the main application. Moreover, it is capable of analyzing the composition of medicines in the form of tablets, which can be useful in cases where there is no packaging for the specified drug or the label is damaged, as well as to recognize counterfeit medicines. Further, an efficient m-health prototype system was developed to test the created application, which includes a portable NIR spectrometer, a smartphone, a WiFi router for Internet access and a remote cloud platform for data processing. Afterward, based on the prototype developed, the network traffic generated in the analysis process was intercepted and analyzed to further evaluate its characteristics and develop models for m-health service delivery. At the same time, a group of models was developed to test Quality of Service (QoS) solutions for providing molecular analysis service using NIR spectrometers and the Internet and based on the intercepted traffic. Finally, AnyLogic simulation environment is utilized to perform the simulation, where four different sceneries are implemented, namely basic scenario, the scenario with preprocessing (error checking), the scenario with buffering, and the scenario using Edge Computing. Additionally, the average service time and the amount of data transferred were compared for each scenario. Simulation results show that preprocessing (error checking), data buffering, and Edge Computing can significantly reduce the network latency and volume of transferred data.

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MNN and LSTM-based Real-time State of Charge Estimation of Lithium-ion Batteries using a Vehicle Driving Simulator

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***Abstract*—Lithium-ion batteries (a type of secondary battery) are now used as a power source in many applications due to their high energy density, low self-discharge rates, and ability to store long-term energy. However, overcharging is inevitable due to frequent charging and discharging of these batteries. This may result in property damage caused by system shutdown, accident, or explosion. Therefore, reliable and efficient use requires accurate prediction of the battery state of charge (SOC). In this paper, a method of estimating SOC using vehicle simulator operation is proposed. After manufacturing the simulator for the battery discharge experiment, voltage, current, and discharge-time data were collected. The collected data was used as input parameters for multilayer neural network (MNN) and recurrent neural network–based long short-term memory (LSTM) to predict SOC of batteries and compare errors. In addition, discharge experiments and SOC estimates were performed in real time using the developed MNN and LSTM surrogate models.**

Keywords—Lithium-ion battery; state of charge; multilayer neural network; long short-term memory; vehicle driving simulator; real time

I. Introduction

With the recent occurrence of energy depletion and environmental pollution, research on eco-friendly and efficient energy sources is underway [1]. Recent developments in lithium-ion (Li-ion) batteries have yielded large energy density batteries with very low power losses (due to self-discharge) and longer life spans, making them the primary source of power for various electronic devices [2]. Secondary batteries, such as Li-ion batteries, also provide economic and environmental advantages over primary batteries used once and discarded. However, due to the nature of secondary battery operations (frequent charging and discharging), overcharging is a likely occurrence, in which case the electronic device may be shut down or risk an explosion [3]. Accurate identification and management of battery conditions are essential to solving these problems and ensuring efficient optimal usage and stability. A battery management system (BMS) helps manage energy efficiently and reliably when using secondary batteries. Related research has been recently undertaken as Li-ion battery applications continue to increase [4]. One of the parameters used in a BMS is the state of charge (SOC), an indicator of the remaining capacity of a battery, with 100% representing full capacity and 0% representing no capacity. It can also represent the state of health and the output performance of the battery [5]. Therefore, accurate prediction of SOC can help device users achieve better efficiency and reliability.

Methods for estimating SOC include open-circuit voltage (OCV), current calculation, and artificial neural network models. OCV is a method of estimating SOC by measuring voltages in open circuits where no current flows. However, it is difficult to achieve a real-time SOC estimation with this method due to the long stabilization time needed to attain equilibrium for accurate measurement [6]. The current accumulation method is easy to implement by randomly setting the initial SOC and then charging and discharging the battery to calculate the amount of change in the current. However, if the initial SOC setting deviates considerably from the expected value, the SOC error accumulates, making it difficult to estimate SOC accurately [7]. In this paper, The SOC was estimated using artificial neural networks. Artificial neural networks are implemented based on human brain structures and are used in various fields, such as pattern recognition, identification, and classification, and can efficiently learn the relationships between input and output parameters [8]. A battery SOC estimation using artificial neural networks does not require consideration of the battery's internal electrical and chemical properties. This method is advantageous for estimating nonlinear models and can operate on low-specification processors [9][10]. The artificial neural networks used in this paper are a multilayer neural network (MNN) and a recurrent neural network (RNN)-based long short-term memory (LSTM). An RNN is a neural network in which the previous learning information (history) influences the current learning [11]. It is structured in a chain format and is advantageous for predicting time-series data. However, as the amount of data increases, a gradient loss problem occurs; hence, an LSTM was employed to eliminate this challenge [12].

In this paper, a vehicle driving simulator has been built to estimate the SOC of Li-ion batteries based on the actual vehicle's output. After completing the production of the vehicle driving simulator, a Highway Fuel Economy Test (HWFET), a vehicle fuel efficiency test mode used by the U.S. Environmental Protection Agency, was applied to the motor driver in the simulator. Voltage, current, and discharge time data for the battery were collected according to the output of the simulator. The values were verified in real time and used as input parameters in the MNN and the LSTM for estimating the SOC.

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The composition of this paper is as follows. Section 2 describes the internal configuration and fabrication process of the vehicle driving simulator used in the battery discharge experiment. Section 3 introduces the proposed SOC estimation algorithm; MNN, one of the types of artificial neural networks used in this paper; and RNN-based LSTMs, and describes learning methods for SOC estimation. Section 4 describes the experimental process of the proposed algorithm, the number of input parameters, and the results of SOC estimation according to the MNN and the RNN used. Finally, Section 5 describes the conclusions of this study and plans for future studies.

II. Vehicle Driving Simulator

In this paper, a vehicle driving simulator has been created to determine the SOC change of the battery due to the actual vehicle output. The composition of the simulator is shown in Fig. 1.

The simulator is a two-wheel-drive vehicle consisting of a remote control (RC) car frame, four tires, two DC motors (rated voltage 12V and 6000 RPM), one motor driver (MDD3A), one Arduino pro-mini module, and one D.C. converter. The motor driver and Arduino pro-mini modules are devices designed to control the revolutions per minute (RPM) of the motor to be implemented according to the HWFET. It was applied as the driving cycle of the discharge experiment simulation, with the D.C. converter continuously adjusting the input voltage to the motor rated voltage of 12V. The HWFET, defined by the U.S. Environmental Protection Agency, is a test cycle to measure the fuel efficiency on a highway, as shown in Fig. 2.

Hyundai Motor's Avante Sports A.D. 16 model and 255/40/18 (cross-section width, flat ratio, wheel size) tire specifications were set as models to simulate precisely the actual vehicle speed. The motor's output in the simulator was controlled by the proposed motor driver for the HWFET after calculating the speed of the actual vehicle using the third gear ratio, tire specifications, and the motor RPM of the simulator. Fig. 3 shows a photograph of the built vehicle driving simulator. The simulator was fixed using steel frames and MC nylon board to prevent the simulator from moving or losing its balance due to motor vibration during the discharge experiment simulation.

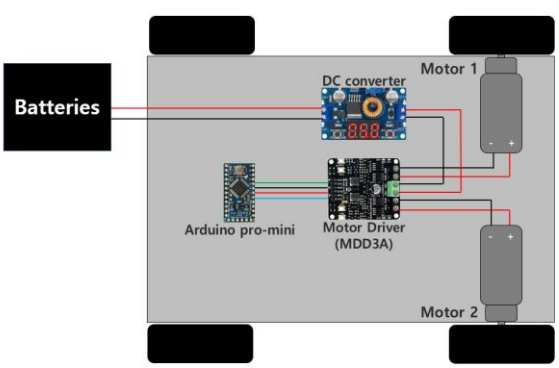


Fig. 1. Configuration of the Vehicle Driving Simulator.

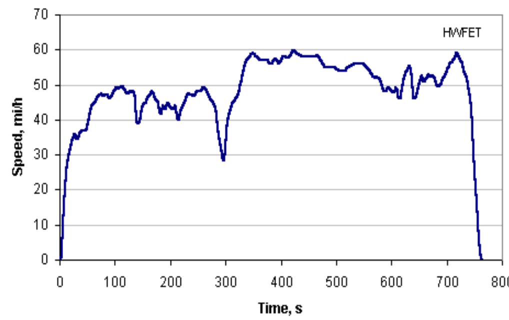


Fig. 2. Highway Fuel Economy Test Cycle.

Fig. 3. The Vehicle Driving Simulator.

III. SOC Estimation Algorithm using the Proposed Neural Networks

A. Battery SOC Estimation Method

This paper proposes a method to estimate the SOC of a battery using a vehicle driving simulator, MNN, and LSTM. Fig. 4 illustrates the proposed battery SOC estimation algorithm. First, four fully charged batteries are connected in series and used as input voltage for the simulator. Next, the discharge experiment was conducted using a vehicle driving simulator. After the discharge experiment was completed, the measured voltage, current, and discharge-time data were sent to a PC using voltage and current sensors and the Arduino modules. After processing the transmitted data with different numbers of input parameters, Four MNN and LSTM models were developed respectively to estimate the SOC of each battery.

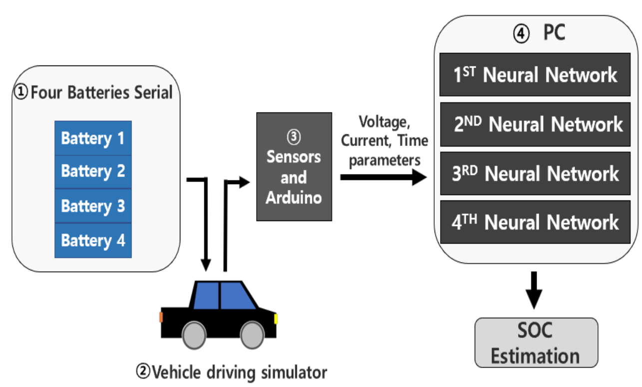


Fig. 4. SOC Estimation Diagram of Batteries using Artificial Neural Networks and a Vehicle Driving Simulator.

B. Multilayer Neural Network

A MNN compensates for the shortcomings of perceptrons, which can only be learned limitedly because they consist only of linear functions, by adding one or more hidden layers between the input and output layers in the tomographic perceptrons. The MNN is shown in Fig. 5.

Single-layer perceptrons use the feedforward method to update weights. In MNN, feedforward and backpropagation are used, unlike a single-layer perceptron. Feedforward updates weights in the direction of the output layer at the input layer, but backpropagation is a method of reducing the error by updating weights in the direction of the input layer at the output layer. Backpropagation is divided into four stages; calculate output values using existing weights as a first step. Then, in two steps, a partial value of the error of each weight is subtracted from the existing weight. The next three steps are stage 2 for all weights. Finally, steps 1 through 3 are repeated for the given number of lessons. Fig. 6 illustrates the concept of a backpropagation [13]. Due to these MNN learning methods, they can be expressed more complexly than single-layer perceptrons and are also advantageous for classification and numerical prediction.

The process of updating the weights of the backpropagation is shown in (1) through (5). First, the input and output values used to calculate net radio waves can be obtained from the following expressions.

$$net_j = \sum_i w_{ij} X_i \tag{1}$$

$$(X_j = f(net_j + \theta_j) \tag{2}$$

where net_j is the input value of the node j, w_{ij} is the weight of the i-th node entering the j-th node, $f(net_j + \theta_j)$ is the activation function, X_i, X_j is the output value of the previous node entering the *i* and *j* nodes, and θ is the input bias value. When updating weights with errors, the required values can be obtained in the following expressions:

$$\delta_i = \lambda(l_i - X_i) f'(X_i) \tag{3}$$

$$\delta_j = \lambda \sum_i \delta_i w_{ji} f'(X_j) \tag{4}$$

where *l* is the label value and *X* is the output value. Weights can be updated using the above obtained δ.

$$w_{ji}(t+1) = w_{ji}(t) + \eta \delta_j y_i \tag{5}$$

where *t* is the time index and η is the learning rate.

C. Long Short-Term Memoryn

The LSTM is an RNN-based neural network developed to improve the gradient loss problem as the distance between the learning data increases. Fig. 7 shows the structure of an LSTM, consisting of three gates and one cell state.

Equations (6)–(11) describe the process of the LSTM operation. First, the forget gate uses sigmoid functions to keep or discard previous and current learning data while the input gate stores the values to be updated in the cell state using the sigmoid and other activation functions. It then updates the cell state by adding the resulting values of the forget gate and input gate. Finally, the output gate determines the final output value by multiplying the current and previous data with the value from the sigmoid function, the value obtained by the cell state, and the value obtained using the activation function [14].

$$f_t = \sigma(w_f \cdot [h_{t-1}, x_t]) + b_f \tag{6}$$

$$i_t = \sigma(i \cdot [h_{t-1}, x_t]) + b_i \tag{7}$$

$$\tilde{C}_t = tanh(w_C \cdot [h_{t-1}, x_t]) + b_C \tag{8}$$

$$C_t = f_t \cdot C_{t-1} + i_t \cdot \tilde{C}_t \tag{9}$$

$$O_t = \sigma(w_O \cdot [h_{t-1}, x_t]) + b_O \tag{10}$$

$$h_t = O_t \cdot \tanh(C_t) \tag{11}$$

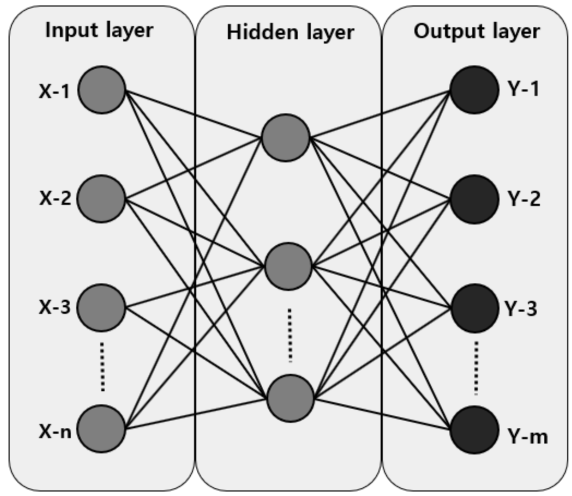


Fig. 5. Structure of the Multilayer Neural Network.

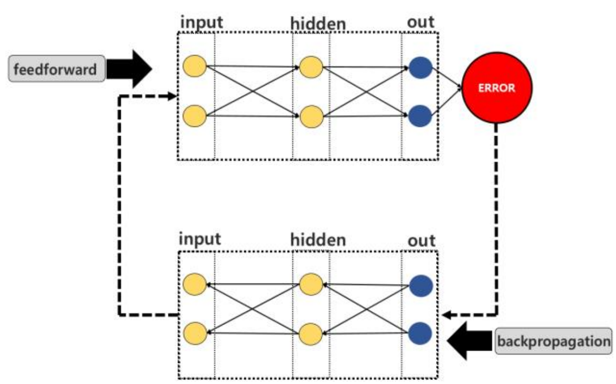


Fig. 6. Schematic of the Back Propagation Algorithm.

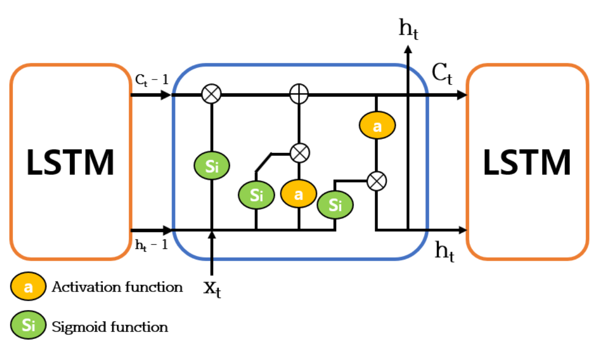


Fig. 7. Structure of the Long Short-Term Memory (LSTM).

where h_{t-1} is the previous data, x_t is the current data, w and b are the weights and biases, f_t is the value of the previous and current data, i_t and $\tilde{C}_t$ are the values of the sigmoid and the activation functions, C_t is the updated value of the cell state, O_t is the value of the output gate, and h_t is the final output value.

IV. Experimental Process and Result

A. Experimental Process

In this research, a battery discharge experiment was conducted using a vehicle driving simulator. The equipment used in the discharge experiment included four Li-ion batteries (rated capacity 1300 mAh), a power supply, a battery chamber (to ensure fire safety due to the strong reactivity of lithium ions [15]), a vehicle driving simulator, voltage and current sensors, and an Arduino module. Fig. 8 shows the equipment used for the discharge experiment and the experimental environment.

The battery charging and discharging experiments were conducted by connecting the four batteries in series. As expected in series connections, the same amount of current flows through each circuit. However, frequent charging and discharging may result in charge imbalances depending on the electrical and chemical characteristics of the battery and the battery operating environment [16]. Therefore, this experiment used a cell balancing module to equalize the voltage of the four batteries during charging and discharging. The sequence of experiments for estimating each battery's SOC is as follows: First, by defining a SOC of 100% (full capacity), the four batteries were fully charged at constant voltages of 4.2 volts via a power supply. Next, the batteries were kept for a stabilization period of about an hour to overcome charge imbalances. The discharge experiment was then conducted using the four batteries as input voltages for the vehicle driving simulator. Fig. 9 shows a voltage graph of changes during one cycle discharge experiment for each battery. The x-axis is the number of samples, and the y-axis is the voltage of each battery. The number of samples per cycle is between 2000 and 2200. One cycle of the discharge experiment is defined as from the beginning of the discharge experiment to the point when some of the four batteries are discharged and the vehicle driving simulator is shut down. The above steps were then repeated to obtain the voltage, current, and discharge-time data for 10 cycles. The discharge-time data used in this experiment is time data that accumulates from the beginning to the end of the discharge experiment.

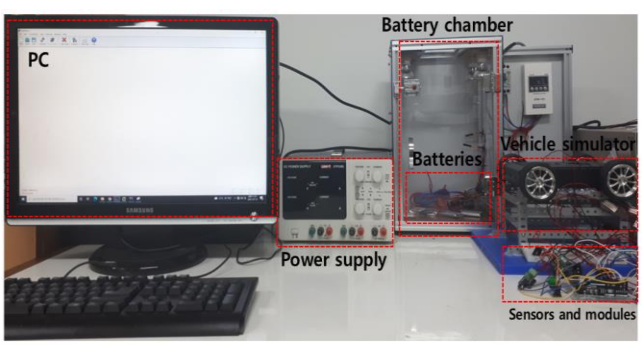
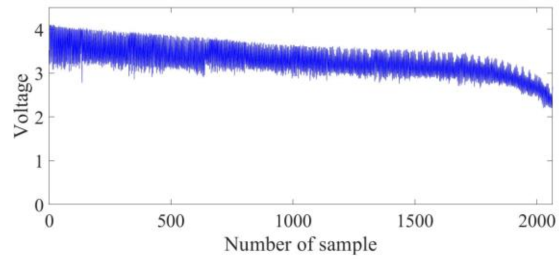
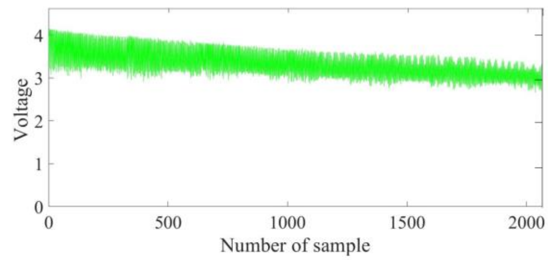


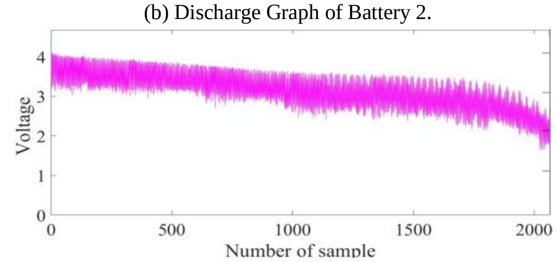
Fig. 8. Experimental Environment and Equipment.



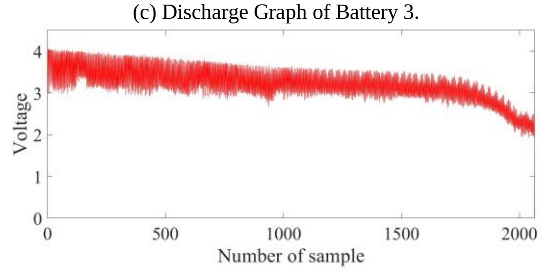
(a) Discharge Graph of Battery 1.



(b) Discharge Graph of Battery 2.



(c) Discharge Graph of Battery 3.



(d)Discharge Graph of Battery 4.

Fig. 9. Cycle Discharge Experiment Voltage Graph for (a) Battery 1, (b) Battery 2, (c) Battery 3, and (d) Battery 4.

These data were later transferred to a PC and then used as input parameters for the MNN and LSTM to estimate the SOC of each battery (Python, TensorFlow, and Keras package were used for learning). To obtain the SOC to be used as the training label for the MNN and LSTM, four fully discharged batteries were charged individually and then any initial SOC was specified. The current data acquired by the discharge experiment are then computed using the current calculation method. The current calculation method is presented as

$$\mathrm{SOC(t)} = \mathrm{SOC(0)} - \int_0^t \frac{I(t)}{C_n} dt \qquad (12)$$

Where SOC(t) stands for SOC at time t, I(t) stands for current at time t, SOC(0) stands for initial SOC, and C stands for battery rated capacity.

Using MNN and LSTM, four models were developed that use different input parameters. The learning structure of MNN and LSTM used in this document is shown in Fig. 10 and 11.

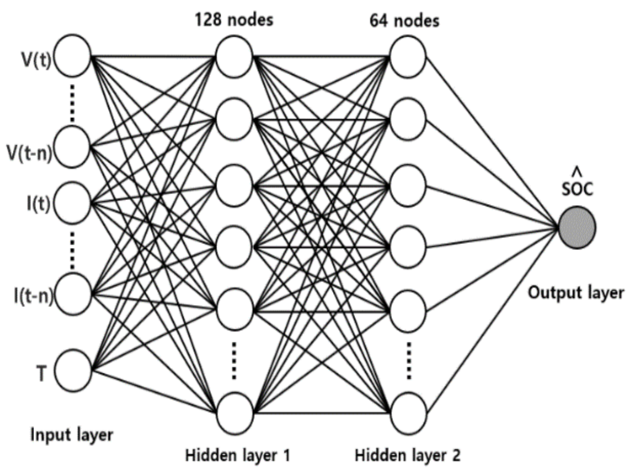


Fig. 10. Structure of the used MNN Models.

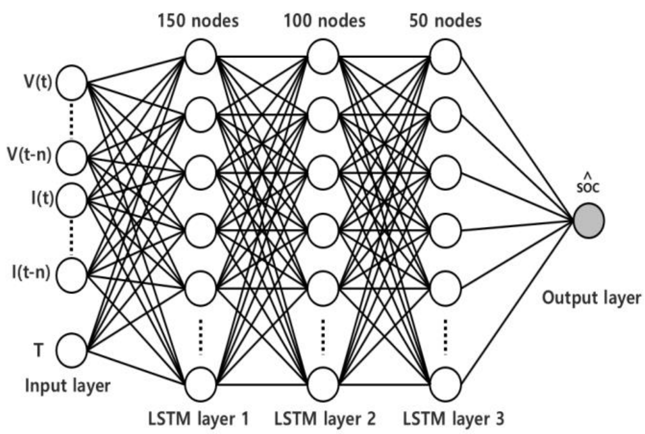


Fig. 11. Structure of the used LSTM Models.

One discharge time data was added to each of the four MNN models and four LSTM models constructed using 2, 3, 4, and 5 values for voltage (V) and current (I) data. In Fig. 10 and 11, the input parameter (T) represents the time from the beginning to the end of the discharge experiment, and voltage and current data are sampled once every two seconds of the discharge experiment. The four MNN models all have the same hidden layer structure, consisting of two layers. The first node count was 128, the second node count was 64, and the sigmoid was used as an activation function. There was one node in the output layer and the model was trained using 15000 epochs. The four LSTM models all have the same hidden layer structure, consisting of three LSTM layers. The first node count was 150, the second node count was 100, the third node count was 50, and the sigmoid was used as an activation function. There was one node in the output layer and the model was trained using 5000 epochs.

B. *Experimental Result*

In this paper, The SOC was estimated by adding different numbers of voltage and current data and one discharge-time parameter to MNN and LSTM. The SOC errors of each estimated battery using MNN are presented in Table I and Fig. 12. The models were named according to the number of input parameters employed: 5-input (two voltages, two currents, one discharge time), 7-input (three voltages, three currents, one discharge time), 9-input (four voltages, four currents, one discharge time), and 11-input (five voltages, five currents, and one discharge time). Each battery's error function was estimated using the mean absolute error (MAE) and is given as

$$\mathrm{MAE} = \frac{1}{n}\sum_{i=1}^{n}|y_i - \hat{y}| \tag{13}$$

where n is the number of data to be calculated, y is the estimated value of SOC, and $\hat{y}$ is the predicted value using the current loading method and MNN or LSTM.

The SOC error estimated by the 5-input model showed that all four batteries had errors between 1% and 2%. The SOC error of the 9-input and 11-input models resulted in less than 1% errors on some batteries. The SOC error of the 11-input model is relatively smaller than that of the other models. The least estimated error (0.83%) among the four models was Battery 3 on the 9-input model. Consequently, the SOC estimation performance of 9 and 11 input models is considered to be superior to that of other models. The SOC error of each estimated battery using LSTM is presented in Table II and Fig. 13.

TABLE I. SOC ESTIMATION ERROR USING MNN MODELS

	Battery1	**Battery2**	**Battery3**	**Battery4**
5-input	1.68%	1.71%	1.41%	1.54%
7-input	1.31%	1.52%	1.02%	1.15%
9-input	1.35%	1.31%	0.83%	1.01%
11-input	0.95%	1.07%	0.89%	1.1%

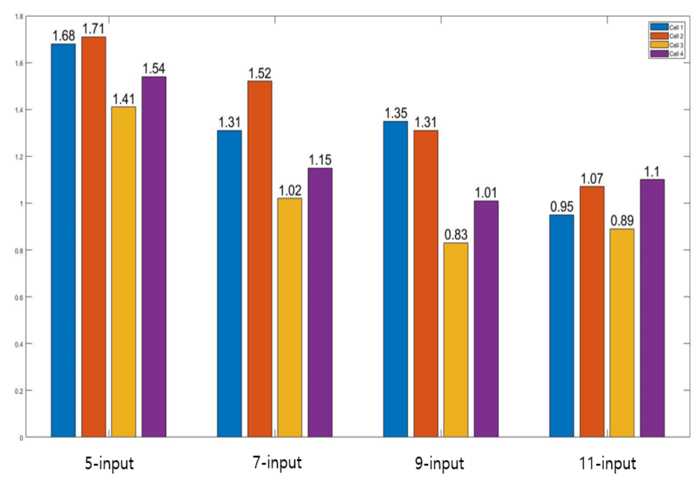


Fig. 12. SOC Estimation Error Graph using MNN Models.

TABLE II. SOC ESTIMATION ERROR USING LSTM MODELS

	Battery1	**Battery2**	**Battery3**	**Battery4**
5-input	1.6%	1.83%	1.82%	1.69%
7-input	0.82%	0.89%	0.8%	0.85%
9-input	0.65%	1.18%	0.76%	0.88%
11-input	0.61%	1.02%	0.73%	0.78%

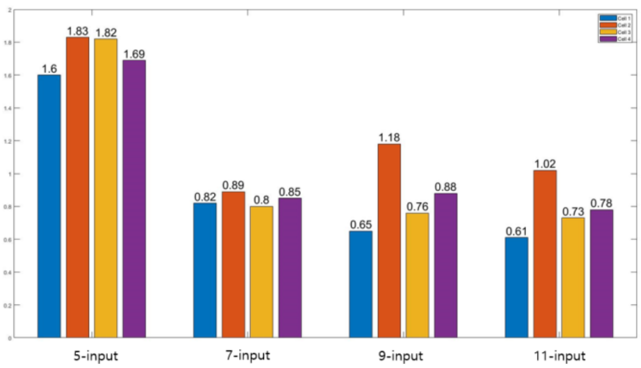
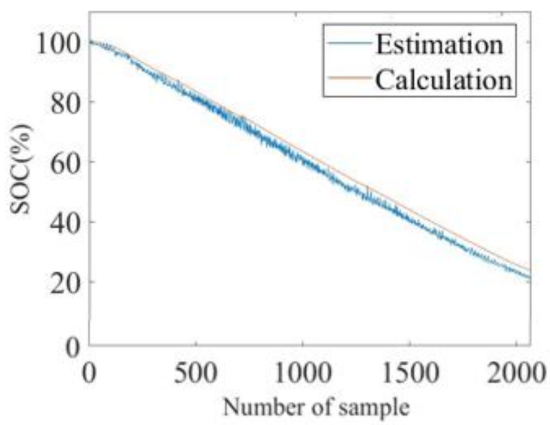
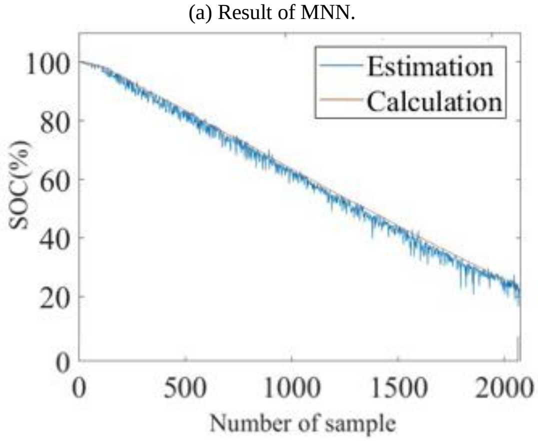


Fig. 13. SOC Estimation Error Graph using LSTM Models.

The SOC error estimated by the all models showed that all had errors below 2%. The SOC error of the 7~11-input models resulted in less than 1% errors on some batteries. The SOC error of the 11-input model is relatively smaller than that of the other models. The least error (0.61%) was Battery 1 on the 11-input model. Consequently, it is judged that the SOC estimation performance of 11 input models is superior to that of other models. Figs. 14 through 17 graph the SOC estimation results of the MNN models and LSTM models (Estimated Result of Battery 1). “Estimation” label and “Calculation” label in Fig. 14, 15, 16 and 17 show estimated values using artificial neural networks and SOC label values obtained using current integration, respectively.

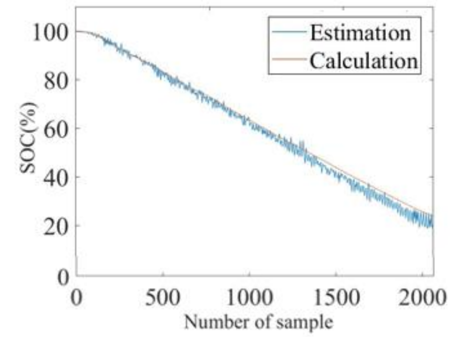


(a) Result of MNN.

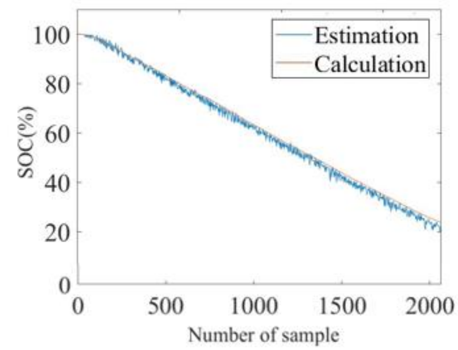


(b) Result of LSTM.

Fig. 14. SOC Estimation Result of 5-Input Model for (a) MNN and (b) LSTM.

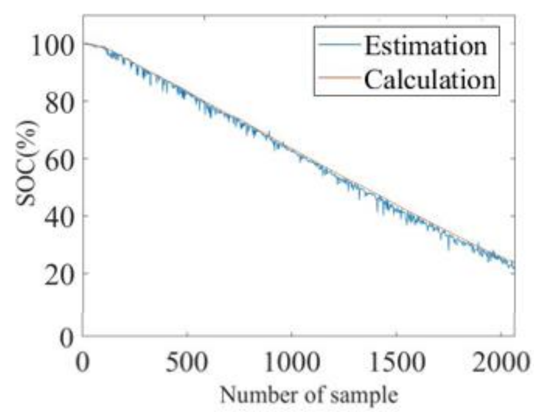


(a) Result of MNN.

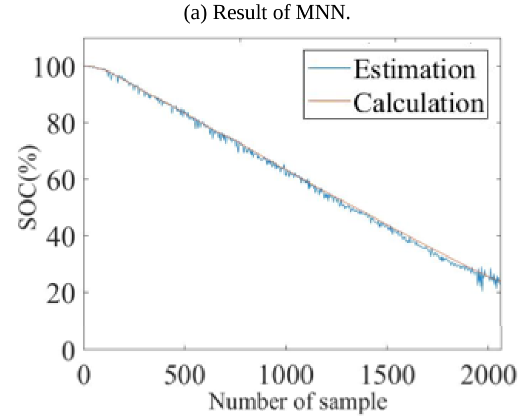


(b) Result of LSTM.

Fig. 15. SOC Estimation Result of 7-Input Model for (a) MNN and (b) LSTM.

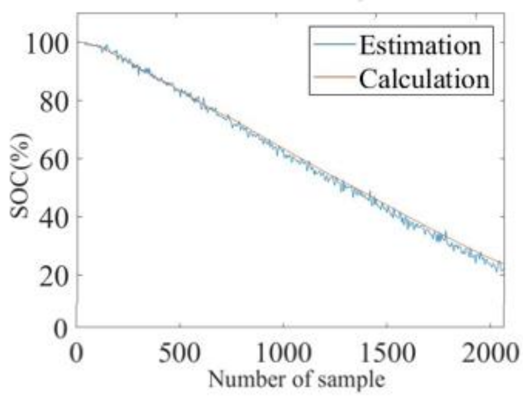


(a) Result of MNN.

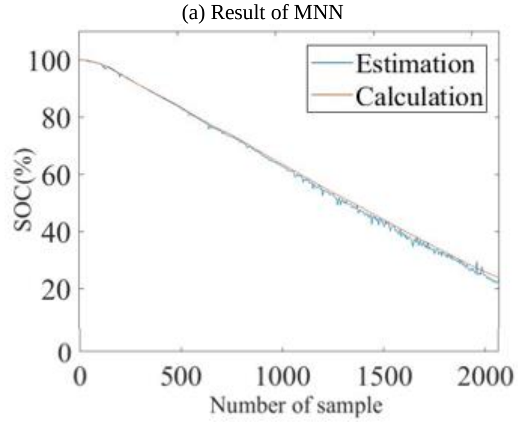


(b) Result of LSTM.

Fig. 16. SOC Estimation Result of 9-Input Model for (a) MNN and (b) LSTM.



(a) Result of MNN



(b) Result of LSTM

Fig. 17. SOC Estimation Result of 11-Input Model for (a) MNN and (b) LSTM.

Using the LSTM in Table II, the estimated error of MNN in Table I was compared, and the estimated error of MNN in 5-input model was relatively small compared to LSTM. However, in other models with 7 to 11 inputs, LSTM's estimation performance can be determined to be superior to MNNs because the estimation error of LSTM was small.

According to Chemali et al. [17], the results obtained using LSTM showed an error of 0.573% at a fixed temperature of 10℃. The model with the smallest error in this paper was the LSTM 11-input model, with a SOC error of 0.61% for Battery 1, which was larger than that of Chemali et al. However, in the work by Chemali et al., the error in an environment with ambient temperature of 25℃ was 0.774%, indicating that the error in this work was smaller.

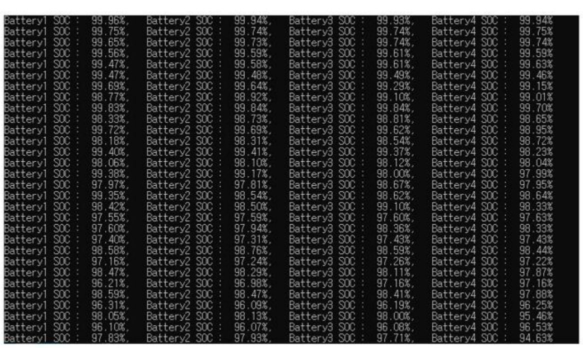


Fig. 18. SOC Estimation Display a LSTM Model.

Discharge experiments using the LSTM models in this work for SOC prediction in battery SOC estimation were made in real time. Fig. 18 shows a screen that uses the LSTM model to make real-time estimates. Real-time estimates were made using 7 inputs and 9 inputs, with the estimation errors shown in Table III.

TABLE III. REAL-TIME ESTIMATION ERROR WITH LSTM MODEL

	Battery 1	**Battery 2**	**Battery 3**	**Battery 4**
7-input	1.79%	2.63%	1.9%	2.25%
9-input	1.79%	1.23%	2.07%	1.88%

The estimation results show that the error in real-time estimation is relatively higher than that shown in Table III. It is judged that the error increased due to the influence of noise generated during real-time estimation. However, it was confirmed that real-time SOC evaluation using the learning model is possible.

V. CONCLUSION

In this study, we built a vehicle driving simulator to monitor changes in battery SOC when driving an actual vehicle and then applied the HWFET (cycle mode) to conduct discharge experiments. The SOC was estimated based on the obtained voltage, current, and discharge-time data using the vehicle driving simulator. We used that data as input parameters for the MNN and LSTM. We used four MNN and four LSTM models and compared the estimation errors of each model by adding two, three, four, or five voltages and currents and one discharge-time parameter. The SOC error of the four MNN models was less than 2%. Among the MNN models, the 9-input and 11-input models have errors of less than 1% in some batteries. The SOC estimation results of the LSTM model showed an estimation error of less than 2% for all four models and an overall error of less than 1% for the 7-input model and 11-input model. Estimation results from both MNN and LSTM show that the estimation error of the 11-input model is small compared to other models. Moreover, the SOC error results of LSTM were relatively small compared to MNN except for the 5-input model. Therefore, it was determined that the SOC estimation performance of LSTM was superior to that of MNN. Discharge experiments were conducted in real time using the 7-input LSTM model and 9-input LSTM model that were established for SOC estimation and SOC was estimated.

The discharge experiment was conducted using Li-ion batteries as input voltages for the vehicle driving simulators by checking and acquiring voltage and current data variations, which were expected to be applicable when driving an actual vehicle.

Further studies will consider conducting a discharge experiment by applying another driving cycle test, the Federal Test Procedure 75 (FTP-75) for city driving test used by the U.S. Environmental Protection Agency, to the vehicle driving simulators. The data obtained through the discharge experiments would be used as input parameters for MNN and LSTM to compare the SOC estimation and errors.

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Learning Optimum Number of Bases for Indian Languages in Non-negative Matrix Factorization based Multilingual Speech Separation

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***Abstract*—Non-negative matrix factorization-based audio source separation separating a target source has shown significant performance improvement when the spectral bases attained after factorization exhibits latent structures in the mixed audio signal comprising multiple speaker sources. If all the sources are known, the spectral bases may be inferred on priority by using a training process on the database of isolated sources. The number of bases inferred for a source should not include bases matching spectral patterns of the interfering sources in the audio mixture; otherwise, the estimated target source after separation will be incorporated with undesirable spectral patterns. It is difficult to distinguish and separate similar audio sources in an overlapped speech, leading to a complex speech processing task. Therefore, this research attempts to learn an optimum number of bases for Indian languages leading to successful separation of target source in multi-lingual multiple speaker speech mixtures using non-negative matrix factorization. The languages used for utterances are Hindi, Marathi, Gujarati, and Bengali. The speaker combinations used are female-female, male-male, and female-male. The optimum number of bases which was determined by evaluating improvement in the separation performance was found to be 40 for all the languages considered.**

Keywords—Indian languages; optimum number of bases; non-negative matrix factorization; speech separation

I. Introduction

Separating audio source signals from a monaural recording is a complex problem. This problem is aggravated if the audio sources in the recording are overlapped with each other and are similar. A successful solution to these problems is compositional models, where the magnitude spectra of an audio signal can be decomposed into a linear combination of “spectral bases”. Therefore, the bases for all the sources comprising the mixture combine linearly to constitute the magnitude spectra of the mixed audio signals. This leads to the fact that optimum estimation of the contribution made by the bases of a particular source to the mixed signal will help separate the said source.

Lee & Seung demonstrated non-negative matrix factorization (NMF) as a method that learns to represent a face as a linear combination of its “basis images”. According to them, the basis images are local features corresponding to the parts of faces [1], [2]. The data matrix, in this case, is a non-negative image database which is NMF decomposed into two non-negative matrices, the part of the faces and their weights such that the original data matrix is approximated by their product.

The different domain using NMF expresses the columns of M (the data matrix) in terms of positively weighted sums of the columns of B (the parts or the basis vectors). Table I shows some examples of relations between the data matrix and the basis vectors or bases for some domains.

Apart from the above examples, this model became phenomenally successful as an audio source separation algorithm. It usually decomposes the spectrogram of an audio mixed-signal (M) into several “spectral bases” (B) and “temporal weights or activations” (A).

When the original data is corrupted, i.e., an audio signal is interfered with by simultaneous speakers and noise, NMF methods fail to learn an effective subspace or basis function matrix from the original data space or data matrix. In such cases, the basis functions matrix is populated with trained bases obtained by NMF decomposition of individual audio sources participating in the mixture. This basis functions matrix is then passed as a factor for data matrix (audio mixed signal) factorization, and only the activations matrix is updated. The estimated sources are obtained by multiplying the basis vectors with their corresponding activations. This procedure is called supervised source separation, as shown in Fig. 1, which provides improved separation performance. The limitation of such an approach is that it should know the sources prior to factorization.

TABLE I. Data Matrix and its Parts

Domain/ Application	M (data matrix)	B (parts or bases)
Computer Vision [1] [2]	Pictures of faces	Pictures of facial features
Document Clustering [3]	Documents	Base topics
Bioinformatics [4]	Spectra of chemical mixtures	Spectra of component molecules

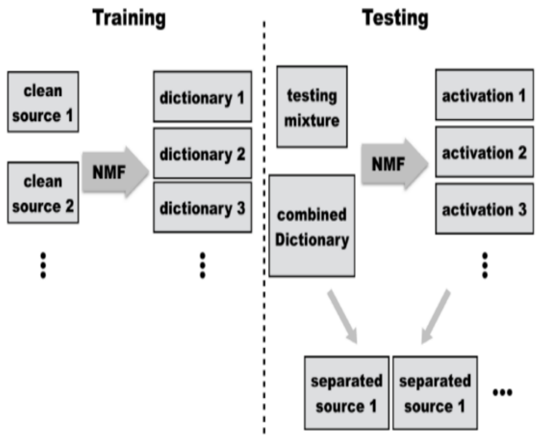

Fig. 1. Supervised Source Separation using NMF.

The separation problem is well studied for separating multiple speakers speaking the same language from a monoaural recording, but many multilingual overlapped speech recordings are not explored. A multilingual speech signal scenario is very usual in India, where 22 official languages are spoken. Any speech processing application addressing such speech mixtures as speech forensics or home assistant devices may find it challenging to recognize the desired speech leading to underperformance. Adding a speech separation module as a pre-processor to these applications in an Indian speech mixture scenario will help in improving the performance of segregating the desired speech. This leads to our motivation to further enhance the speech separation performance by identifying the bases obtained from individual sources, as discussed above in Fig. 1, which may better represent the mixed speech signal or the data matrix. The number of bases inferred for a speech source should not include bases matching spectral patterns of the interfering sources in the mixture; otherwise, the estimated target source after separation will be incorporated with undesirable spectral patterns.

Therefore, the objective is to learn the number of optimum bases representing individual Indian language speech sources to enhance the separation of one signal or all the participating signals from a multilingual, multiple-speaker speech signal comprising different Indian languages using NMF. The languages used are Hindi, Marathi, Gujarati, and Bengali. The evaluation metrics for separation performance were carried out by the "Blind Source Separation evaluation (BSS EVAL)" toolkit [5].

The organization of the paper is as follows: Related works are explained in Section 2, Methodology is elaborated in Section 3, Section 4 demonstrates the implementation, and Section 5 provides the results and discussion. The conclusion is given in Section 6.

II. Related Work

M.N Schmidt and R.K Olsson [6] proposed sparse NMF based source separation, which learns an over-complete set of non-negative basis vectors for each source. An over-complete set is a set where the number of bases is more than the spectral representation dimensions. According to the authors, better separation is achieved in separating individual audio sources from a mixture if each source is represented on an over-complete basis vector. The authors concluded that the dictionaries capture fundamental properties of speech; that is, the basis functions resemble phonemes. Convolutional NMF considers "spectro-temporal patterns" as bases instead of simple amplitude spectra in the paper [7]. This NMF variant extract cross-column patterns as single bases, therefore, capturing the temporal dependencies within bases.

Most of the previously discussed NMF-variants ignore individual signal phases and use the phase of the mixture signal while reconstructing the separated respective signals. This drawback of earlier NMF-variants introduced audible artifacts. Kameoka et al. in 2009 [8] presented an NMF-variant which allowed complex values and was given the name "complex non-negative matrix factorization". The authors proposed a mixing model called complex NMF established in the complex-spectrum domain. This paper aims to represent any observed complex spectrum where fewer active magnitude spectrum bases are paired with an arbitrary phase spectrum. King and Atlas in [9] named Complex NMF as "complex matrix factorization" (CMF). In this case, "each time-frequency point is multiplied with a phase term that allows each spectral base to assume the phase to fit the mixed-signal best", maintaining the non-negativity constraints of bases and activations.

Discriminative training of the NMF basis functions was introduced in [10], which generalized the model with separate analysis and reconstruction basis functions. Another research [11] selects active-set Newton algorithm (ASNA) for overcomplete NMF (over-complete set of basis functions), which outperforms other conventional source separation techniques. Simplex volume minimization [12] successfully estimates the source model, which learns an identifiable spectral basis. Working with dense basis matrix factors is allowed by these identifiability conditions. In addition, the basis matrix may have a full-column rank without any constraint imposed.

A pair of dictionaries was used for analysis and reconstruction in the paper [13]. It increases separation performance at low latencies, which is accomplished by utilizing shorter synthesis frames. According to the authors, if computational power is sufficiently available, this methodology may be applied to real-time applications. "Low-latency output allows a human listener to directly use the results of such a separation scheme without a perceptible delay". A binary subspace learning for the bases was proposed by [14]. Orthogonal NMF (ONMF) [15] adds orthogonality constraints to NMF in addition to the non-negativity constraint on one or both factors: the columns of B (bases) and the rows of A (activations) are required to be orthogonal. Newer variants of NMF [16] are being developed for hyperspectral and multispectral image fusion, which are yet to have been experimented with for audio source separation. Technologies other than NMF deliver competitive results in speech separation or enhancement, for example, deep learning neural networks (DNN) [17], but they are successful only with large training data. NMF is still suitable for a smaller dataset.

The number of bases retained during training differs for all the supervised speech separation discussed in existing research studies. Moreover, most of the research is based on a single language, primarily English or native languages. Therefore, studies on speech mixtures comprising different languages need attention. It is also crucial to identify the optimum number of bases or parts representing the latent structure of the data (mixed-signal) for successful separation of its comprising different language speech signals.

III. METHODOLOGY

The reason behind the successful separation of audio sources from a mixed signal using supervised NMF is the selection of an optimum set of basis vectors. Therefore, this section explains the methodology and the evaluation measures quantifying the separation performance. The performance is compared based on the metrics generated by BSS EVAL.

A. Non-negative Matrix Factorization

Positive Matrix Factorization was introduced by Paatero and Tapper in 1994, which was later coined as non-negative matrix factorization (NMF) [1]. Lee & Seung in 2001 [2] popularized NMF as a non-negative constrained algorithm capable of learning parts of faces from a facial image database favorably called image bases. The linear combination of these weighted parts constitutes each face. NMF decomposes the data (in this paper speech spectrogram) into basically two “non-negative components”. The components are the “basis functions matrix,” representing the spectrum of bases, and the “coefficient matrix,” representing the activation coefficients of the bases in the data as in Fig. 2.

Recognizing NMF’s capability, it was extended to several applications like “audio source separation,” as explained in the Introduction. It separates the audio signal considered as target source from other interfering speakers or noise or music considered as maskers. It is possible to separate all the participating signals present in the audio mixture signal in some cases. The data representation of the mixed audio signal (M) is accomplished using spectrograms. The magnitude of the mixed audio signal (M) spectrogram is decomposed into basically two “non-negative components”. The components are “basis functions matrix” (B) and “weight or activation or coefficient matrix” (A).

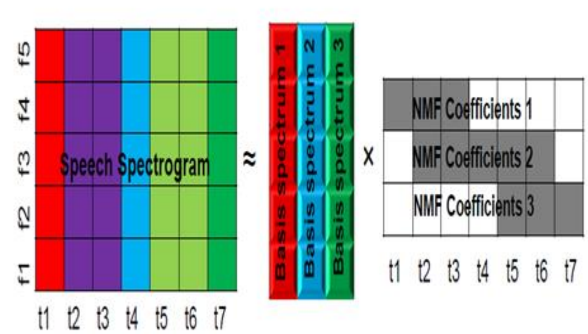

Fig. 2. A Speech Spectrogram is Factorized into bases and its Weights using NMF [25].

The interpretable factorization may be expressed as $M \approx BA$. BA is the matrix multiplication of B and A, where $M \in \mathbb{R}_{\geq 0}^{P \times Q}$ is subjected to the constraints of non-negativity $B \in \mathbb{R}_{\geq 0}^{P \times L}$ and $A \in \mathbb{R}_{\geq 0}^{L \times Q}$.

$P \in \mathbb{R}_{>0}$ is the number of the frequencies representing the spectrum of the mixed-signal M. $Q \in \mathbb{R}_{>0}$ is the time axis representing the mixed-signal M spectrogram. $L \in \mathbb{R}_{>0}$ is the number of the column basis vectors in B and activations row-wise in A. Cost functions along with multiplicative updates converge the non-negative factorization to a substantial approximation. For simplicity, M and BA are represented by X and Y for the following cost function expressions. X_{pq} and Y_{pq} are the elements (*p*=row, *q*=column) of the matrices X and Y, respectively.

The “Euclidean distance” (EUC) between X and Y [2] is given by:

$$\| X - Y \|^2 = \sum_{pq} \left(X_{pq} - Y_{pq}\right)^2 \tag{1}$$

The “Kullback-Leibler divergence” (KL) [2] is the cost function which leads to relative entropy when $\sum_{pq} X_{pq} = \sum_{pq} Y_{pq} = 1$.

$$div(X \,\|\, Y) = \sum_{pq}\left(X_{pq} \log \frac{X_{pq}}{Y_{pq}} - X_{pq} + Y_{pq} \right) \tag{2}$$

Another cost function given below is “Itakura-Saito (IS) divergence” [18]

$$div(X \,\|\, Y) = \sum_{pq}\left(\frac{X_{pq}}{Y_{pq}} - \log \frac{X_{pq}}{Y_{pq}} - 1\right) \tag{3}$$

Both the cost functions are non-increasing, which leads to minimization or convergence. The elements of B and A are initialized either randomly or using some pre-defined methodology with non-negative values. Convergence is achieved by executing the following multiplicative update theorems iteratively:

The EUC ‖ M – BA ‖ is updated by the following rules [2]:

$$A \leftarrow A \circ \frac{B^T}{B^T} \frac{M}{BA} \qquad B \leftarrow B \circ \frac{MA^T}{BAA^T} \tag{4}$$

The divergence *div*(M ‖ BA) for KL uses the following [2] to update rules:

$$A \leftarrow A \circ \frac{B^T \frac{M}{BA}}{B^T.1} \qquad B \leftarrow B \circ \frac{\frac{M}{BA} A^T}{1.A^T} \tag{5}$$

For IS divergence, the multiple updates established by [18] is given by:

$$A \leftarrow A \circ \frac{B^T \frac{M}{(BA)^2}}{B^T.\frac{1}{BA}} \qquad B \leftarrow B \circ \frac{\frac{M}{(BA)^2} A^T}{\frac{1}{BA}.A^T} \tag{6}$$

B. Performance Measures

BSS Eval toolkit presents signal level metrics which evaluates the amount of speech enhancement or improvement and interference reduction. According to [5] the separated or estimated source $\hat{s}$ is expressed as a sum of the target source s_{target} and three types of error as follows:

$$\hat{s} = s_{target} + e_{interf} + e_{noise} + e_{artif} \tag{7}$$

"where s_{target} is part of the estimated source, which is the true source signal modified by a permissible distortion. The term e_{interf} is the error caused by interference from the unwanted sources. The sensor noise represented as the part of the estimated source is e_{noise}. The artifact error term, e_{artif}, is the part of the estimated source perceived as coming from other sounds, like forbidden disturbances and/or 'burbling' artifacts".

The ratios "source to distortion ratio" (SDR), "source to interference ratio" (SIR), and "source to artifact ratio" (SAR) over the audio signals are computed, which determines the relative value of each of these estimated target source and error terms given as follows:

$$\text{SDR:} = 10\log_{10}\frac{\|s_{target}\|^2}{\|e_{interf} + e_{noise} + e_{artif}\|^2} \quad (8)$$

$$\text{SIR:} = 10\log_{10}\frac{\|s_{target}\|^2}{\|e_{interf}\|^2} \quad (9)$$

$$\text{SAR:} = 10\log_{10}\frac{\|s_{target} + e_{interf} + e_{noise}\|^2}{\| e_{artif}\|^2} \quad (10)$$

The mixtures considered in the experiments conducted and mentioned in this paper are assumed to be noiseless. Therefore, only the SDR, SIR, and SAR performance measures are used throughout the experimentation. "SIR measures the quantum of the interfering sources present in the separated or estimated signal. The SAR measures the unwanted energy present in the signal that is not part of either the target or interfering audio signals. Combination of SIR and SAR into one measurement results in SDR".

IV. Implementation

Supervised NMF obtains basis vectors from individual speech sources participating in a mixed speech signal during the training phase. During the testing phase, these speech basis vectors from the training phase are used as the basis vectors matrix, which is one of the factors for the mixed speech signal factorization. The other factor is the activations matrix, which is updated, keeping the basis vectors matrix constant. The multiplication of basis vectors with the respective updated activations provides the separated signals. The experimental setup and evaluation methods engaged in this research are given below:

A. Experimental Setup

Synthetic mixtures of speech signals comprising different Indian languages are selected for the investigation, mainly taken from Hindi, Marathi, Gujarati, and Bengali speech audio databases. Bengali male (SLR37) [19], Marathi female (SLR64) [20], Gujarati male and female (SLR78) [20] multi-speaker speech databases are taken from openSLR (Open Speech and Language Resources) developed by Google. Hindi female, Bengali male, and Marathi male multi-speaker speech databases are taken from TTS voice data from IIIT Hyderabad [21]. Bengali female and male multi-speaker speech databases are also taken from the SHRUTI speech corpus developed by the Indian Institute of Technology; Kharagpur (IITKGP) distributed by the Society for Natural Language Technology Research [22].

The mixed speech signal was created by digitally combining male or female speech utterances of one language with male or female speech utterances of another language. For each language, the training data chosen was 60 utterances ranging from 3.00 to 5.00 seconds. The testing data selected was 5 utterances of similar duration different from training data. The testing data was augmented by combining one language utterance to all 5 utterances of another language, making it 25 utterances. One of the speech signals separated from the mixed speech signal is the target speech signal, and the other speech signal is called the interfering or the masker speech signal. The target speech signal to the masker speech signal is mixed with a target-to-masker ratio (TMRs) of 0 dB.

All the speech audio sources (WAV files) categorized for the training and testing phase were sampled at 16KHz. For the time-frequency (TF) representation, the short-term Fourier transform (STFT) was computed using 1024 points. A 32ms long with a 16ms overlap Hamming window was utilized for the same. The number of basis vectors experimented with for both the sources (all language combinations in this paper) was 40, 75, 100, and 150. The algorithm was executed at 500, 1000, and 1500 test iterations for each number of basis vectors chosen.

The different language speech combinations engaged are Marathi with Bengali, Marathi with Hindi, Hindi with Gujarati, Gujarati with Marathi, and Bengali with Hindi. The NMF cost function used was KL divergence for all the experiments. PYTHON programming language was used for the NMF algorithm with multiplicative updates. Parselmouth, PRAAT in PYTHON [23] was used for the spectrograms.

B. Evaluation

The source separation results were evaluated using the signal level metrics BSS_EVAL tool (SDR-source to distortion ratio, SIR-source to interference ratio, and SAR-source to artifact ratio), which quantifies the speech enhancement or interference mitigation.

V. Results and Discussion

This section analyses the separation performance results to learn the optimum number of basis vectors required for individual speech spoken in different Indian languages in a supervised audio source separation using NMF, which will subsequently help in successful speech separation from a mixed speech signal.

As mentioned in Implementation, the mixed speech signal comprises two speakers of the same or different genders (female-female, male-male, and female-male) speaking different Indian languages simultaneously. The language combinations are Hindi-Gujarati, Hindi-Bengali, Bengali-Marathi, Hindi-Marathi, Marathi-Gujarati. The speaker combinations are female-female, male-male, female-male.

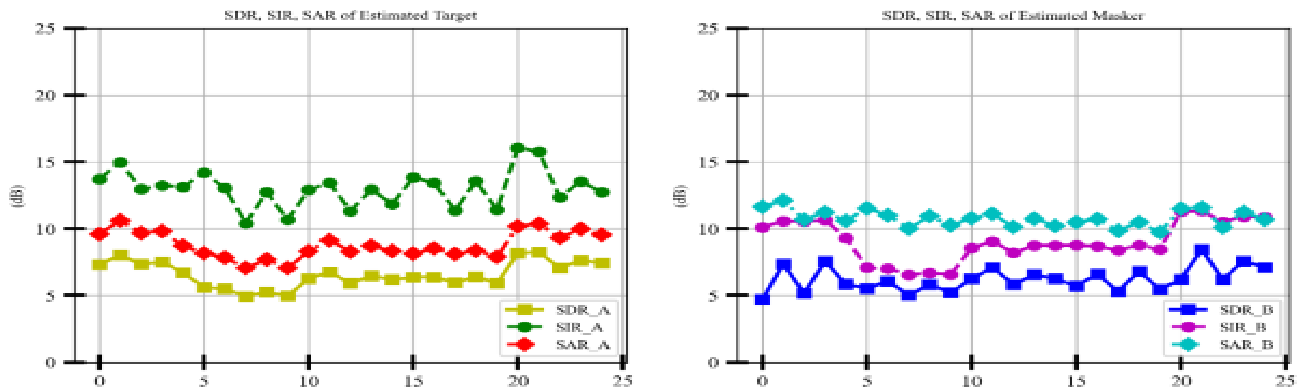

Fig. 3. Speech Separation Performance of Estimated Target (Hindi Female Speech) and Masker (Gujarati Male Speech) from 25 Testing Mixed Signals.

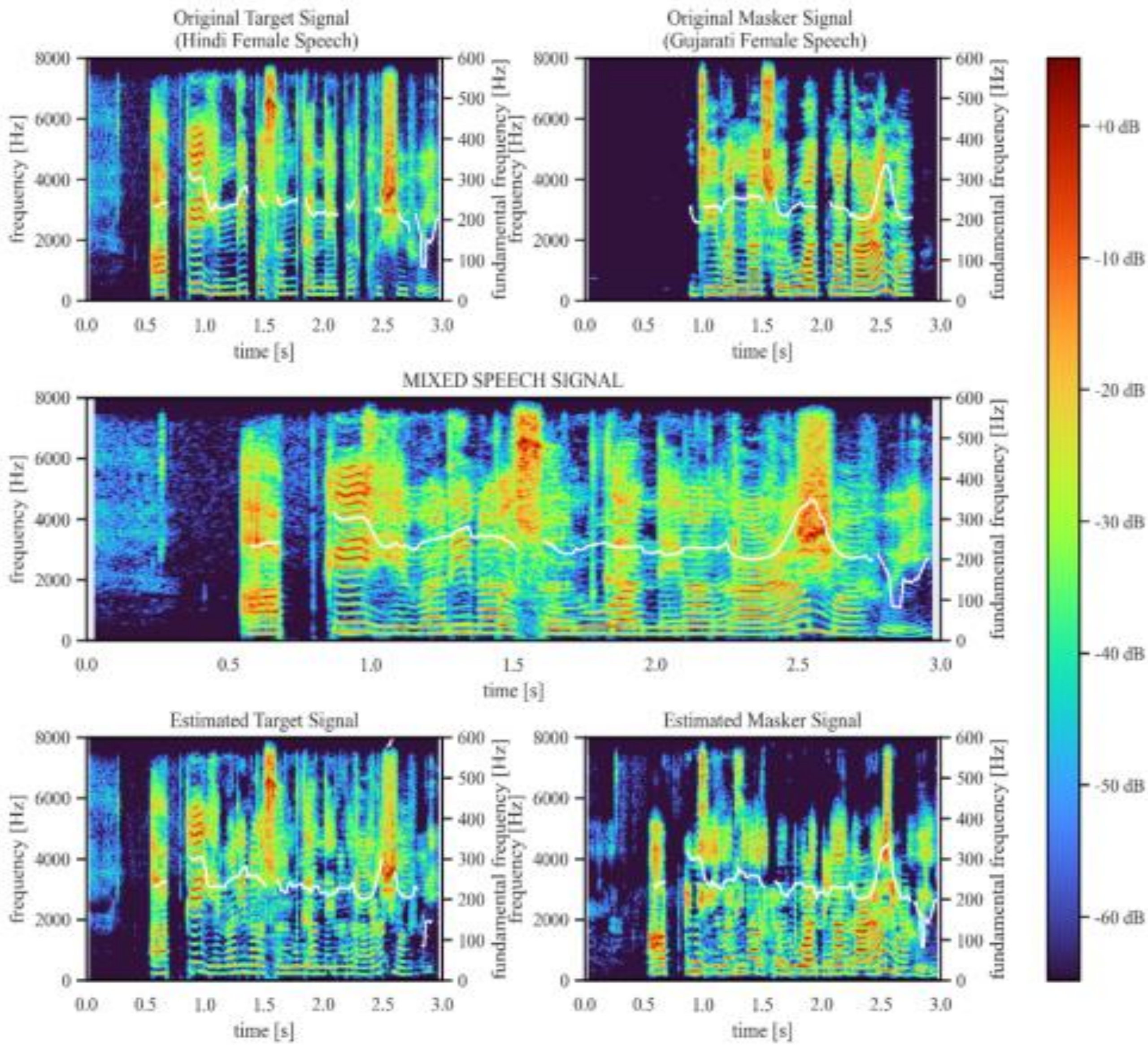

Fig. 4. Spectrograms of Original Target and Masker, Mixed Speech Signal and Estimated Target and Masker for Female-Female Combination.

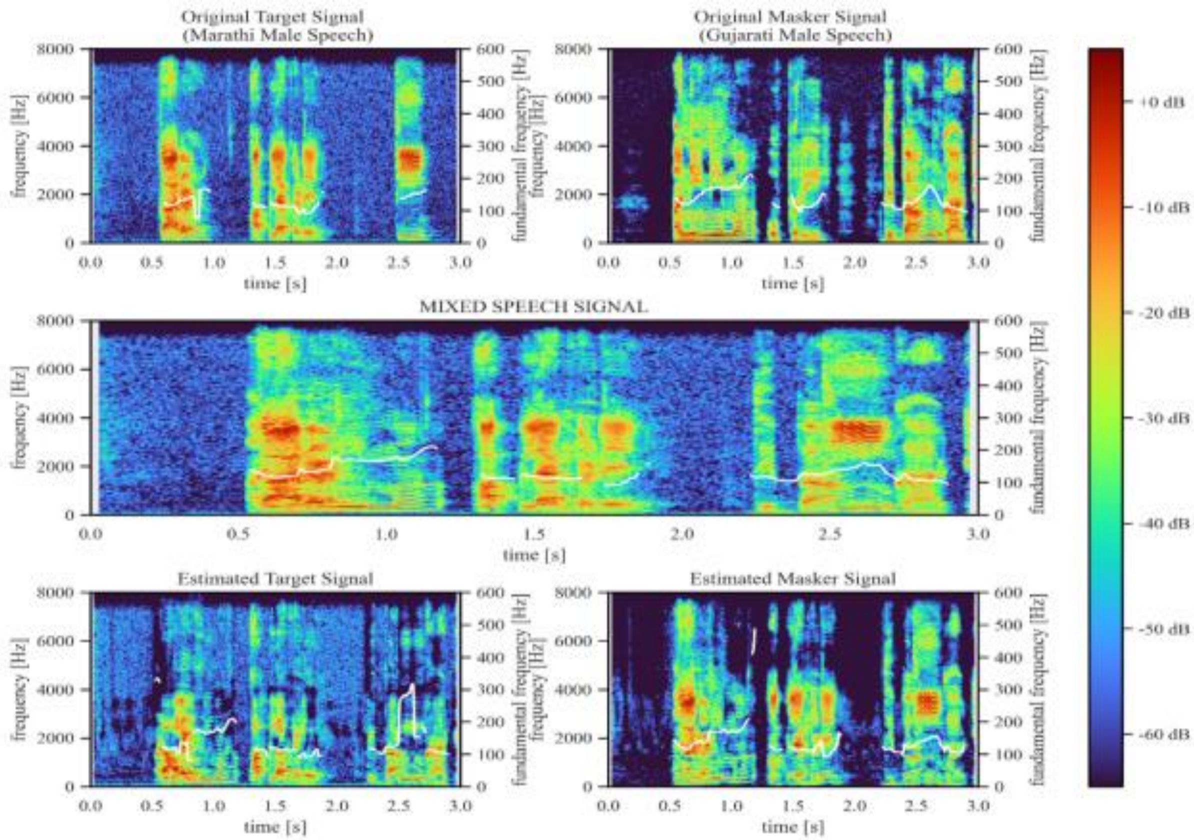

Fig. 5. Spectrograms of Original Target and Masker, Mixed Speech Signal and Estimated Target and Masker for Male-Male Combination Speaking Marathi and Gujarati, Respectively.

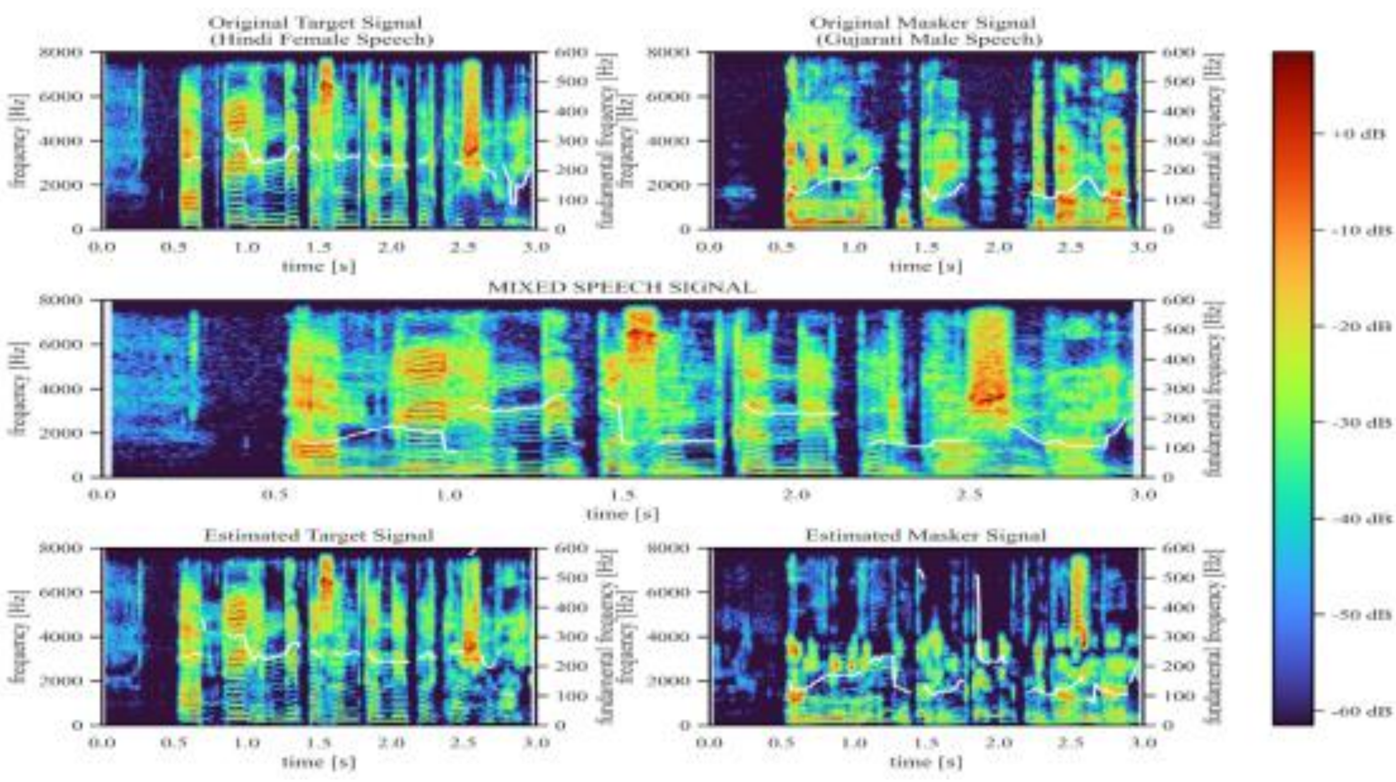

Fig. 6. Spectrograms of Original Target and Masker, Mixed Speech Signal and Estimated Target and Masker for Female-Male Combination Speaking Hindi and Gujarati, respectively.

For each of the combination BSS EVAL parameters, SDR, SIR, and SAR are used to quantify separation quality. As interpreted from the Implementation section, we have 25 mixed utterances in the testing phase; the evaluation parameters were computed for all the separated utterances. The same is displayed in Fig. 3 for one such combination. As evident from the figure, the deviation for the parameter values from the mean value is significantly less, within the range of 2 to 3 dB; therefore, the mean value is considered for this and other language-gender combinations.

Spectrograms are used to display the speech parameters. Fig. 4, Fig. 5, and Fig. 6 show the spectrograms of original target and masker, mixed speech signal, and estimated target and masker for female-female, male-male, and female-male, respectively, which displays speech separation. The pitch is highlighted in the spectrograms to show the interference, which is not a very significant presence in the separated target speech due to the masker speech and vice-versa.

NMF on the mixed speech signal for each pair of language-gender combinations was experimented with for basis vectors 40, 75, 100, and 150 to assess the optimum number of bases. Each set of basis vectors are obtained in the training phase with an updated iteration fixed at 1500. Each set of basis vectors was experimented with three different update iterations in the testing phase, namely 500, 1000, and 1500. For the remaining section, the number of iterations mentioned will be indicative of the testing phase.

The language combinations for female-female speech separation selected are Hindi-Bengali, Hindi-Gujarati, and Hindi-Marathi. The BSS EVAL parameters for one of the combinations (Hindi-Bengali) target speech and masker speech are tabulated in Table II.

TABLE II. BSS EVAL PARAMETERS OF HINDI FEMALE (TARGET) AND BENGALI FEMALE (MASKER) SEPARATED FROM A MIXED SIGNAL

Iteration	**Bases**	**Target**			**Masker**		
500		SDR	SIR	SAR	SDR	SIR	SAR
	40	3.11	4.67	5.60	2.03	3.36	7.64
	75	2.88	4.55	5.42	2.12	2.50	9.51
	100	2.75	2.65	6.65	1.82	1.69	9.21
	150	3.07	3.14	7.49	1.94	1.88	10.49
1000							
	40	2.44	3.04	5.34	1.82	2.00	7.36
	75	2.78	3.92	5.67	2.01	2.22	9.09
	100	2.78	2.77	6.33	1.85	1.90	8.84
	150	2.79	2.65	6.77	1.89	1.66	9.69
1500							
	40	3.62	6.29	5.49	2.24	4.52	8.01
	75	2.87	3.82	5.58	1.96	2.52	8.34
	100	2.92	4.04	5.56	2.03	2.46	8.95
	150	2.94	3.41	6.17	1.97	1.98	9.78

TABLE III. BSS EVAL PARAMETERS OF MARATHI MALE (TARGET) AND GUJARATI MALE (MASKER) SEPARATED FROM A MIXED SIGNAL

Iteration	**Bases**	**Target**			**Masker**		
500		SDR	SIR	SAR	SDR	SIR	SAR
	40	2.43	2.59	6.02	2.46	1.81	7.01
	75	3.61	4.45	7.39	3.42	3.49	9.35
	100	3.04	2.57	7.69	2.86	1.94	9.11
	150	3.29	2.57	9.00	2.94	2.25	9.38
1000							
	40	2.07	1.74	6.47	2.16	1.00	5.91
	75	2.24	1.22	7.49	2.16	0.59	6.73
	100	2.76	2.08	7.09	2.67	1.57	7.88
	150	3.09	2.44	7.99	2.89	1.96	9.31
1500							
	40	2.33	2.39	6.59	2.31	1.82	5.69
	75	2.63	2.45	6.25	2.62	1.80	7.38
	100	2.73	2.34	7.16	2.65	1.38	8.13
	150	3.40	3.14	8.01	3.12	2.81	8.76

The language combinations for male-male speech separation selected are Marathi-Gujarati, Bengali-Gujarati, and Bengali-Marathi. Table III tabulates the BSS EVAL parameters for one of the combinations (Marathi-Gujarati) target speech and masker speech. The language combinations for female-male speech separation selected are Hindi-Bengali, Hindi-Gujarati, Bengali-Marathi, Bengali-Gujarati, and Hindi-Marathi. One of the combinations (Hindi-Gujarati) target speech and masker speech BSS EVAL parameters are tabulated in Table IV.

Comparing the spectrograms of Fig. 4, 5, and 6 reveals that the estimated target and the masker have interferences from the other speaker's utterance, but they are insignificant. Careful observations show the quantum of interference is more in female-female and male-male than female-male combination. It is well understood as NMF is based on spectral bases. More are the similarity in spectral bases of the source speakers; less is the separation performance as it is difficult to distinguish similar frequencies. Therefore, the separation in the female-male combination is better as their speech fundamental frequencies are at different levels (i.e., male: 80-180 Hz and female: 160-250 Hz).

Now let us consider BSS EVAL parameter SDR for an estimated target separated from a different language female-male combination mixed speech signal. The results are shown as 3D bar plots in Fig. 7, 8, and 9, which show the comparison between the SDR of an estimated target separated from a Hindi-Bengali, Hindi-Gujarati, and Bengali-Marathi mixed signal for update iteration 500, 1000, and 1500, respectively. The SIR and SAR values are discussed from the tables mentioned above.

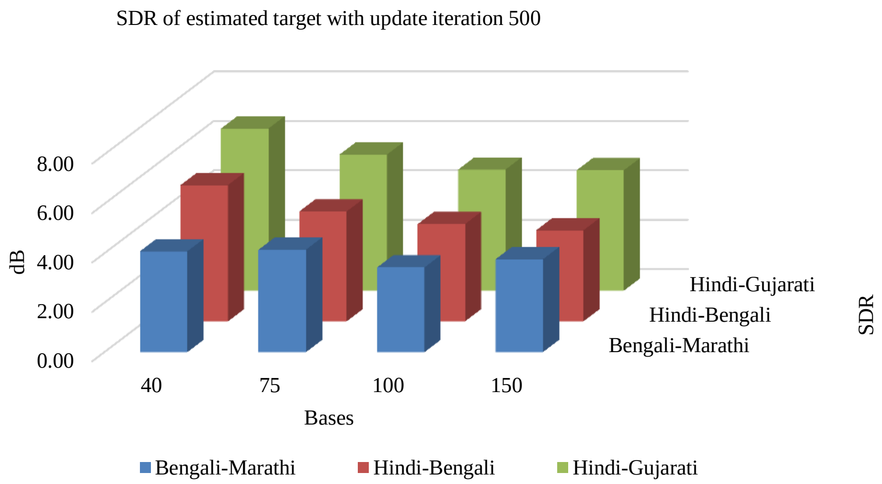

Fig. 7. Comparison of SDR of Estimated Target for Hindi Female (Target)-Bengali Male (Masker), Hindi Female (Target)-Gujarati Male (Masker) and Bengali Female (Target)-Marathi Male (Masker) Separated from a Mixed Signal with Update Iteration 500.

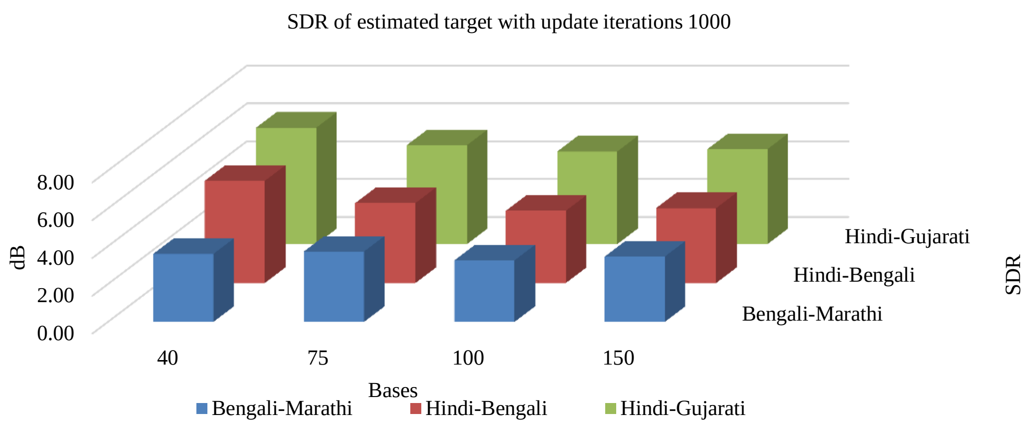

Fig. 8. Comparison of SDR of Estimated Target for Hindi Female (Target)-Bengali Male (Masker), Hindi Female (Target)-Gujarati Male (Masker) and Bengali Female (Target)-Marathi Male (Masker) Separated from a Mixed Signal with Update Iteration 1000.

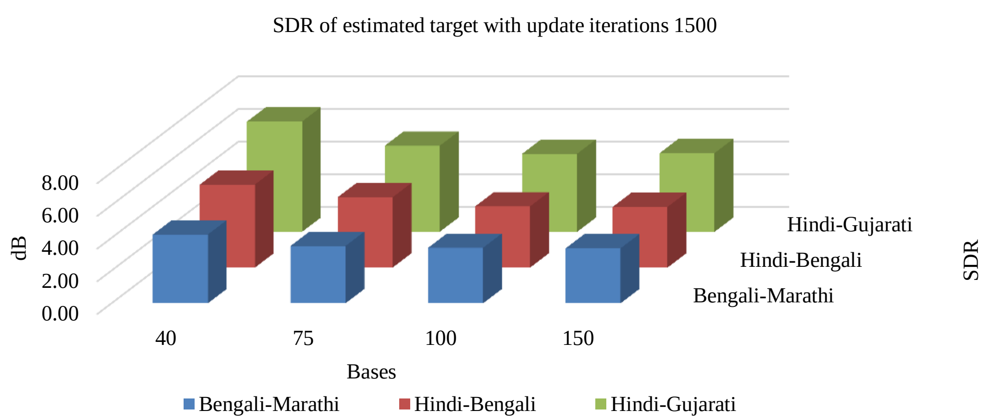

Fig. 9. Comparison of SDR of Estimated Target for Hindi Female (Target)-Bengali Male (Masker), Hindi Female (Target)-Gujarati Male (Masker) and Bengali Female (Target)-Marathi Male (Masker) Separated from a Mixed Signal with Update Iteration 1500.

From the above-mentioned plots, it is observed that the language combination Hindi-Gujarati (female-male) showcases the best result with SDR (estimated or separated target speech) almost nearing 7 dB for update iteration of 500 and 1500 in case of 40 basis vectors. It is also evident from Table IV. Another observation is for most combinations; the SDR is highest for 40 bases though the actual value between the language combination differs by 0.7 dB to 1.5 dB. Though the Bengali-Marathi (male-male) combination shows the lowest results, it shows the highest value of 4.15 dB and 3.72 dB in the case of 75 basis vectors for update iteration 500 and 1000, respectively.

Table III shows the language combination Marathi-Gujarati (male-male) exhibits higher SDR results with 40 basis vectors for 500 iterations followed by 150 bases for 1500 iterations applicable for both the target and the masker speech sources. Table II shows Hindi-Bengali (female-female) language combination for mixed speech signals. It is noticed that SDR values of both the target and the masker speech sources are higher for 500 and 1500 iterations with 40 basis vectors. The SIR result reflects the same as SDR. However, SAR results show higher results with 150 basis vectors for all the iterations, with the only exception in the female-male case where it displays higher results with 40 basis vectors for 1500 iteration. For all the combinations, the effects of update iterations 500 and 1500 are better than 1000. It is noticed that almost all the results suggest 40 basis vectors to be the optimum number after comparing the performance with respect to bases.

As mentioned above, the supervised separation performance of NMF, which is known for its reduced dimensionality depends on the bases representing the latent structures in the mixed speech signal; the objective of this study was to learn the optimum number of bases representing Indian language speech sources in a mixed signal.

TABLE IV. BSS EVAL PARAMETERS OF HINDI FEMALE (TARGET) AND GUJARATI MALE (MASKER) SEPARATED FROM A MIXED SIGNAL

Iteration	**Bases**	**Target**			**Masker**		
500		SDR	SIR	SAR	SDR	SIR	SAR
	40	6.56	13.02	8.77	6.21	9.04	10.77
	75	5.51	11.40	8.05	5.56	6.87	11.34
	100	4.90	9.97	7.80	5.09	5.80	11.74
	150	4.87	9.72	8.28	5.01	5.45	12.07
1000							
	40	6.16	12.95	8.07	6.00	8.56	10.36
	75	5.23	11.89	7.09	5.42	6.72	10.72
	100	4.90	10.78	7.19	5.16	6.04	11.14
	150	5.02	9.08	8.16	5.07	5.91	11.73
1500							
	40	6.75	12.91	9.08	6.31	9.35	10.94
	75	5.26	10.82	7.40	5.35	6.85	10.70
	100	4.78	10.49	7.06	5.08	5.80	11.23
	150	4.81	9.00	7.76	4.93	5.65	11.42

There is no fixed directive to identify the number of bases; the same was learned by utilizing a different number of basis vectors. Each set was used for a different number of iterations in the testing phase. The separation performance is at its best when the bases resemble phonemes or speech sounds of the language. From the literature study, it is known that the languages Hindi, Bengali, Marathi, and Gujarati are Indo-Aryan languages, and their phoneme ranges from 37 (Bengali) to 52 (Marathi) [24]. It is, therefore, understandable that the optimum number of spectral bases required for the individual speech source signal of different Indian languages emerging is 40, after comparing all the speech separation results delivered by NMF.

VI. CONCLUSION

Supervised speech separation of a desired or target speech source from a multi-lingual two-speaker speech mixture is considered, which is very relevant to an Indian scenario as India is a country with a vast population speaking different languages. For successful separation proper set of bases needs to be inferred from the participating speech sources in the mixed signal, i.e., bases matching spectral patterns of the interfering sources in the mixture should not be included as the estimated target source after separation may be incorporated with undesirable spectral patterns. Therefore, this research attempts to learn an optimum number of bases for Indian languages using non-negative matrix factorization. Hindi, Marathi, Gujarati, and Bengali Indo-Aryan languages are used for utterances. The speaker combinations used are female-female, male-male, and female-male.

The optimum number of bases determined by evaluating the separation performance for the individual speech source signal of different languages is observed as 40. This number is nearly like the phoneme sets of the languages engaged, which signifies that separation performance is better when the bases resemble phonemes or the speech language sounds. Though the number of bases is similar for all the languages, the separation performance parameter SDR shows different values for different language combinations. This difference in SDR values needs more insight into language correlation.

A pre-processor separating different language speech sources may be added to several speech processing applications, for example, audio or speech forensics, home assistant devices operating in Indian scenarios, thereby enhancing the applications' performance. The research can be continued for other Dravidian Indian languages, NMF variants and DNN may be utilized depending on the availability of the training dataset.

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Determining Local Hematology Reference Ranges: A Data-driven Approach

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***Abstract*—Hematology is the study of blood, blood-forming organs, and blood diseases. Hematological tests such as Full Blood Count (FBC) can be used to diagnose a wide range of infections and diseases by comparing their results with the standard hematology reference (SHR) ranges. These ranges were established many years ago by considering the Caucasian population and all countries have used them until recent times to measure the healthiness of the people. But these reference ranges can be varied according to various reasons such as dietary habits, geographical location, climate, environmental factors, etc., and the use of them by all countries may not be correct. Many researchers have started research in finding Local Hematology Reference (LHR) ranges. Most of them used statistical analyses which have their limitations. Machine learning is a solution to overcome those limitations. Finding an approach to determine the LHR range based on machine learning techniques is the goal of this research. The dataset was generated using FBC test reports in Sri Lanka. The LHR range of WBC count of healthy adults in Sri Lanka is only addressed in this research. A difference between the SHR range of WBC and the LHR range of WBC is observed.**

Keywords—Hematology science; standard hematology reference range; domestic hematology reference ranges; local hematology reference range; machine learning; white blood cell count

I. Introduction

Medical Science helps to maintain and restore health. It is a combination of diagnosis, prognosis, treatment, and prevention of disease. Medical science can be divided into several sub-sections such as Cardiology, Anesthesiology, Dentistry, Hematology, and Physiology. Hematology consists of four major components as plasma, red blood cells, white blood cells, and platelets. Each of these four components consists of other sub-components. For example, white blood cells contain lymphocytes, monocytes, eosinophils, basophils, and neutrophils. Each of these components has a reference range that is considered to measure the healthiness of a person in Health-related fields.

When considering these hematology reference ranges, they are important to monitoring pathophysiological changes after getting infected with a disease. It can be used to detect diseases such as Dengue fever, HIV, cancer, etc., and track the effects of the given drugs or vaccines for clinical observations. The set of values for hematology reference ranges that are accepted worldwide is called “Standard hematology reference ranges” which were determined many years ago by doing some researches for the Caucasian populations. A Caucasian population is a group of people who are originated from Europe and are also commonly known as “white” or “white-skinned” people.

Gradually, people realize that the Standard hematology reference range can vary due to many reasons such as age, gender, genetics, attitudes, lifestyle, ethnic origin, dietary habits, geographical location, climate, environmental factors, etc.[1]–[3]. Hence the Clinical and Laboratory Standards Institute (CLSI) has recommended that a domestic hematology reference range should be established for each region [2], [4]. As a result, hematology reference ranges per country are the focus of this paper.

When considering Sri Lanka, the population is not a Caucasian population due to their significant variation on factors for which the standard hematology reference ranges were determined.. For example, suppose the minimum hemoglobin reference value of Sri Lankan healthy adults and the minimum value of the standard hemoglobin reference range are ‘x’ and ‘y’ respectively and ‘x’ has become less than ‘y’ due to the nutrition factors of Sri Lankan population. The doctors give medicines for hemoglobin deficiency to people whose hemoglobin values in between ‘x’ and ‘y’ until the local reference ranges are established. But these people may be healthy and do not need to take any medicine as far as the local conditions are concerned. These kinds of situations can happen to any other hematology attribute too. Taking medicine without any illness may cause dangerous side effects too. Therefore, a local hematology reference range is a mandatory thing for every country which is not under the Caucasian population category. As the local hematology reference ranges for Sri Lanka have not yet been determined, the research conducted in the paper is an attempt to fill this gap. Hence, the dataset used in this research was taken by considering the Sri Lankan population.

The paper is organized as follows. We first focus on related works in Section II investigating the impact of standard reference ranges on different populations and different methods in establishing the domestic reference ranges. Section III describes the proposed method in meeting the requirement. Results and Evaluations are described in Section IV. Finally, Section V presents the conclusion of this study.

II. Background Study

Eastern India, China, Morocco, Ethiopia, Sudan, Malawi, Nigeria, and many other African countries have successfully done many kinds of research and established the domestic hematology reference ranges for their countries which contain different values rather than the standard hematology reference range values [1], [2], [5]–[7].

Eastern India researchers had found lower hemoglobin (HB) and platelet (PLT) values when compared to the standard hematology reference ranges. The difference was statistically significant only for the platelet count [2]. The lower hematology reference range values for White Blood cells (WBC), Hemoglobin (HB), Hematocrit (HCT), Mean Corpuscular Volume (MCV), and platelet (PLT) counts which were compared to the standard hematology reference ranges had been found by researchers in Malawi. The research was driven by categorizing the dataset both gender-wise and age-wise. These researchers also compared the received male hematology reference ranges with domestic hematology values of other African countries and found that the male Malawians have lower HB and HCT values than others [5]. A lower reference range for WBC than the standard WBC reference range was found by the Sudanese research team who researched to find a local WBC reference range. The dataset which was used to take this result belonged to a particular city in Sudan. The research team identified that the received result was different by studying two other researches which were also conducted to find domestic WBC reference value considering another two cities in Sudan [1]. A Nigerian research team had analyzed blood and urine samples of males, pregnant females, and non-pregnant females to establish local reference ranges for their country. The different local reference ranges for males and females as well as pregnant females and non-pregnant females were received as the result of the research. They compared their result with reference ranges in the USA. Glucose levels, Urea levels, enzyme levels in the Nigerian population were higher than the USA reference ranges [8]. A local hematology reference range was established by considering both male and female healthy adults in Togo. The blood samples for the research have been taken from 1349 donors who were discovered as healthy. The received ranges have differed from other African countries [9]. In another research, hematology reference ranges were established based on the population of old people in rural southwest Uganda. The received ranges were compared with age groups which are categorized as adults, old people (age between 50 and 65), and very old people (65+). The ranges were changed between age groups [10]. Another research team has established Hematology Reference ranges among Healthy Adults in Bamenda, North West Region of Cameroon. The statistical analysis was used to determine the ranges [11].

Most of these researches were driven by considering age, gender, the country-wise or different area in the same country and were found different reference ranges if the considered dataset did not belong to the Gaussian country. Hence the researchers have focused to establish a local reference range to their countries. The blood samples were taken from the donors who were selected carefully by considering various conditions such as BMI value, medical history, and so on to generate a dataset. The number of data records that were used to establish the local hematology reference range in those countries was less than 1000. It may not enough to decide a local reference range for the whole country. Most of them used statistical analysis such as the Mann-Whitney U test, Chi-square test, t-test, and so on to establish those local hematology reference ranges. Hence, the dataset is statistically analyzed and described by using statistical theories. Most statistical theories define limitations to take a good result. In general, if the dataset contains huge data records then it will help to make a better output. But, because of the data limitation consideration, a huge dataset may not even give efficient results in statistical analysis. Every statistical theory may not apply to a certain dataset. And statistical analysis cannot be efficiently used to make predictions or find hidden patterns.

In general, most data-driven studies were handled by using data mining and machine learning concepts to avoid the above-mentioned problems. Many kinds of research in the medical sector have already used data mining and machine learning concepts to get efficient outcomes[12]–[14].

III. Methodology

Sri Lanka is a South Asian country. It is a tropical island with hot and humid weather all over the year. The population used in this research is Sri Lankan adults with age over 21 years and the data set used for the study is extracted from the Full Blood Count (FBC) test reports from a sample of the population. The sample contains both healthy and unhealthy people. Ethical approval is mandatory for this research as the research works with human medical data.

When considering the hematology components, some of them (dependent components) have an interrelationship with other components (independent components). The normal values of dependent hematology components may change as the independent component changes. For example, White blood cells (WBC) have two categories as granulocytes and non-granulocytes. Each of these categories has five types of white blood cells in human blood as Lymphocytes, Monocytes, Eosinophils, Basophils, and Neutrophils. The task of each of these white blood cells is given below.

- Lymphocyte: Generate antibodies, fight with inflection and viral cells. Also, it has B-lymphocyte, T-lymphocyte, and natural killer cells.
- Monocyte: Attacks chronic infections if present.
- Basophil: Sensitive when occurring allegories.
- Eosinophil: Working with the immune system's responses.
- Neutrophil: Helps to remove fungi and bacteria from the body.

All of these white blood cell types help to be healthy and highly affect the hematology components. When you take the FBC report, it shows leukocyte value (total WBC value) as well as values for five types of WBC cells. In this research, only the leukocyte value was considered. The normal value for leukocytes is taken when all WBC cell types follow normal values.

Data mining techniques and Machine Learning concepts are used to define the new approach which will be introduced via this research to determine local hematology reference ranges.

The general steps involved in the new approach are given in Fig. 1. A local hematology reference range for WBC count is only checked using the approach and a similar procedure can be used to determine local reference ranges of other hematology components.

A. Data Preparation

Various types of tests are used in hematology science such as the Full Blood Count (FBC) test, C-reactive protein (CRP) test, liver function tests, thyroid function tests, etc. Only the FBC test reports are considered to extract the required hematology reading as it is the most common test and shows all the main components of hematology.

As the initial data set obtained contained various types of blood tests, for example, WBC, on multiple rows, it was processed and restored to reflect all the individual's data on a single row as shown in Fig. 2. The values of Lymphocyte, Monocyte, Basophil, Eosinophil, and Neutrophil are stored as count values instead of percentages. A bivariable "Health State" is generated by using the standard hematology reference ranges of other hematology tests without considering the total WBC (leukocyte) value as a local hematology reference range for WBC count has experimented in this research. The Health State takes two values; "H" to identify the healthy persons and "UH" to unhealthy.

The 604 records are taken from the initial dataset for this research.

- 477 people in the dataset whose Lymphocyte value, Monocyte value, Basophil value, Eosinophil value, and Neutrophil value lie between the standard hematology reference range.
- 110 people in the dataset whose health state is equal to "H" generated by considering the other hematology reference ranges without considering the total WBC hematology reference range.
- 90 people in the dataset are healthy by considering all components in standard hematology reference ranges including the total WBC hematology reference range. This group of people will be called "SH" in further works in this research.

Preprocessing is one of the major steps in the Data Mining process and the dataset is explored for this purpose. The following preprocessing tasks were exercised to prepare the dataset for the data mining task.

1) *Removed unique attributes from the dataset.*
2) *Removed unwanted fields from the dataset.*
3) *Converted all data types to nominal.*
4) *Grouped data as necessary.*
5) *Set class attribute as "health state".*
6) *Visualized data:* This helps to take a proper image of the selected dataset. The visualization of the data is very important to make pre-decisions about every attributes before the analysis.

B. Classification Model

Building a classification data model is the next step. Classification can be applied to both structured and unstructured datasets. The classification technique categorizes new data instances into classes by learning through an experienced/training dataset where the classes of each instance of it are already given. When applying a classification algorithm for the training dataset, it separates each data point into given classes. This is the model that is created using a classification algorithm. The accuracy of the classifier is assessed on a separate data set called testing data set by checking the correctly classified records. There are two types of classification algorithms that are mostly used for data analysis. In Binary Classification, the class attribute has only two categories, but it has more than two categories in Multi-Class Classification. Each classification assumes that one data point belongs to only one class and non-class attributes of each data point must be independent of each other and discrete.

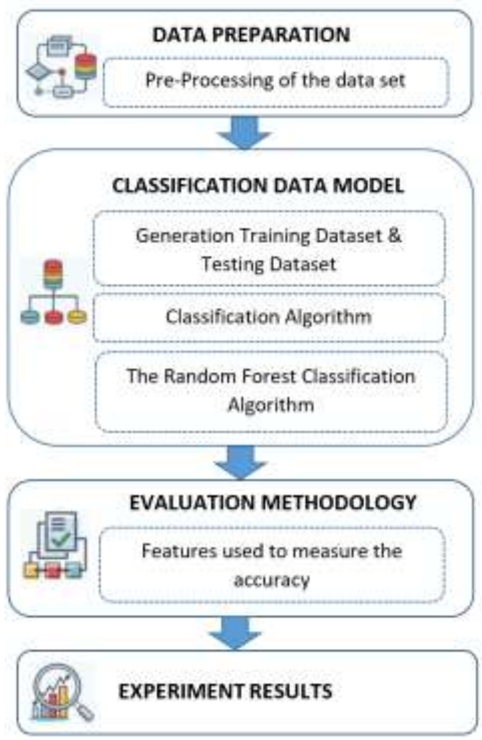
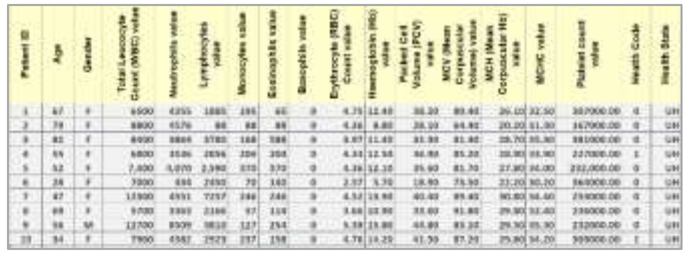


Fig. 1. Methodology Diagram.



Patient ID	Age	Gender	Total Leucocyte Count (WBC) value	Neutrophils value	Lymphocytes value	Monocytes value	Eosinophils value	Basophils value	Erythrocyte (RBC) Count value	Haemoglobin (Hb) value	Packed Cell Volume (PCV) value	MCV (Mean Corpuscular Volume) value	MCH (Mean Corpuscular Hb) value	MCHC value	Platelet count value	Health Code	Health State
1	67	F	6500	4255	1885	195	65	0	4.75	12.40	38.20	80.40	26.10	32.50	387000.00	0	UH
2	78	F	8800	6576	88	88	88	0	4.26	8.80	28.10	65.90	20.20	31.30	167000.00	0	UH
3	82	F	8900	3864	3780	168	588	0	3.87	11.40	31.90	81.40	28.70	35.80	381000.00	0	UH
4	55	F	6800	3586	2856	204	204	0	4.33	12.50	36.90	85.20	28.90	33.90	227000.00	1	UH
5	52	F	7,400	4,070	2,590	370	370	0	4.36	12.10	35.60	81.70	27.80	34.00	232,000.00	0	UH
6	28	F	7000	490	2650	70	140	0	2.37	5.70	18.90	75.50	23.20	30.20	360000.00	0	UH
7	47	F	12300	4951	7257	246	246	0	4.52	14.90	40.40	89.40	30.80	34.60	259000.00	0	UH
8	69	F	9700	3303	2166	97	114	0	3.66	10.90	33.60	91.80	29.80	32.40	230000.00	0	UH
9	58	M	12700	8509	3810	127	254	0	5.38	15.80	44.80	83.20	29.30	35.30	232000.00	0	UH
10	34	F	7900	4582	2923	237	158	0	4.78	14.20	41.50	87.20	25.80	34.20	309000.00	1	UH

Fig. 2. Dataset.

It is needed to find which classification algorithm is suited for analyzing the dataset and achieve the final goal. There are many classification algorithms available in literature but the tree-like algorithms are the most commonly used because of their ease of implementation and easier to understand compared to other classification algorithms [15]–[17]. Random Forest, Random Tree, REP Tree, LMT, J48, and Hoeffding Tree algorithms are such algorithms.

1) The Random Forest Tree (RFT) classification algorithm: Random Forest Tree (RFT) algorithm is a supervised learning algorithm categorizing under the decision trees. The word "Forest" is included in the name of the algorithm hence it makes a bunch of trees. It makes 500 trees in default. The bootstrapping techniques are used to make 500 samples from the dataset to make 500 trees. The algorithm uses ensemble methods to produce the final solution. The random forest algorithm uses horizontal filtering (make samples by considering the different variations of the dataset) as well as vertical filtering (make samples by considering ranks of the attributes) techniques. The main advantage of using a Random Forest algorithm is controlling the overfitting of the data set with predictions [18], [19].

2) Random Tree (RT) classification algorithm: Random Tree (RT) algorithm is also a supervised learning algorithm. The algorithm uses ensemble methods bagging technique to generate a random set of data from which to build a decision tree. The random tree uses k number of attributes at each node of the decision tree but no control over the overfitting of the data set [20].

3) REP Tree classification algorithm: The REP (Reduced Error Pruning) Tree is the simple and most comprehensible decision tree which is used to reduce error pruning strategy. It's a convenient decision tree learner that creates a decision or regression tree with feature selection using information gain based on class variable and prunes it with reduced error pruning. The tree traversal was performed using the REP algorithm from bottom to top, and then each internal node was checked and replaced with the most frequent class with the most concern about the tree accuracy, which must not be reduced. This technique will be repeated until no further pruning reduces the accuracy [20].

4) LMT classification algorithm: The basic structure of a Logistic Model Tree (LMT) is a regular decision tree structure with logistic regression functions at the leaves. A tree structure is made up of a set of non-terminal nodes and a set of terminal nodes. The LMT approach deals with both numeric and nominal attributes, and missing values, as well as binary and multiclass target variables. Induction trees and logistic regression are combined in LMT. Cost-complexity pruning is used in LMT. The speed of this method is much slower than the others [21].

5) J48 classification algorithm: Quinlan's C4.5 algorithm is used to create J48. It builds the tree by selecting the best attributes at each node using the gain ratio. Each feature of the dataset divides it into small partitions to rank the attributes based on criteria that each partition is more consistent with respect to the class outcome. The attribute with the highest rank is used to split the data set. The algorithm will ideally terminate when all the instance in each partition belongs to one class. J48 creates a decision node based on the class's predicted estimations. The J48 decision tree can handle specific characteristics, data with lost or incomplete attribute estimations, and variable attribute prices. Pruning can improve accuracy in this situation [17], [21].

6) Hoeffding Tree (HT) classification algorithm: The Hoeffding Tree (HT) algorithm is one of the most basic algorithms for both stream data and static data classification. In the case of stream data, it can learn from huge data streams incrementally and at any time, given that the distribution of producing examples does not change over time. It generates decision trees in the same way as the standard batch learning approach does. Mathematically, Hoeffding trees and decision trees are connected. The HT technique is based on the basic principle that minimum sample size can frequently be sufficient for determining the best splitting attribute [22].

C. Evaluation of the Methodology

A trained classifier performs the function of assigning new data items in a given 255 collection to a target category or class by using two approaches.

1) Holdout method: as shown in Fig. 3, in training a classifier, the data set is separated into the training data set and test data set. In general, the training dataset contains 2/3 of data from the dataset, and the rest of the data is categorized as the testing dataset[23], [24].

2) 10–folds Cross-Validation (10-folds CV): k-folds Cross-Validation (CV) is a commonly used training control technique in learning a classifier. It applies the resampling technique to evaluate classification algorithms. The dataset is split into k number of groups. It randomly selects 1 data group as the testing dataset and the remaining groups (k-1) as the training dataset. Then build the data model by using the training dataset and evaluates it by using the testing dataset. Here each group has a chance to select as the testing dataset at a time and select as the training dataset at k-1 times. In general, 10-fold CV is used [23], [24].

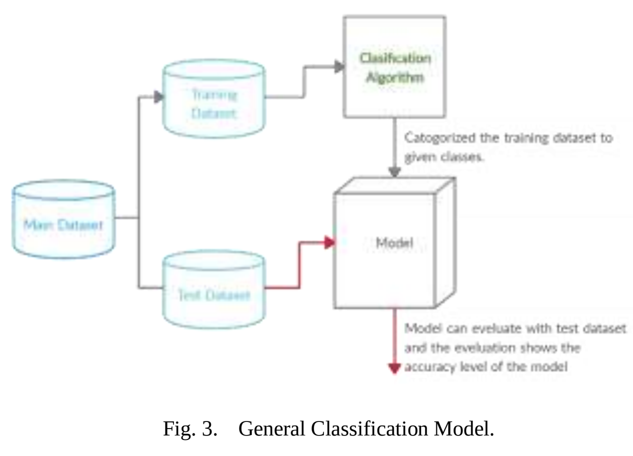


Fig. 3. General Classification Model.

There are several metrics to measure the accuracy of the classifier built.

1) Correctly classified instances and incorrectly classified Instances: This shows how many instances are correctly classified by the model and how many instances are incorrectly classified by the model. it gives numerical value as well as the percentage. Therefore, if it shows a higher value for the Incorrectly Classified Instances than Correctly Classified Instances then the built model is not good. And also, if it shows Correctly Classified Instances as 100% then it is also not a good outcome as the data over-fitting to the model may more validation error. The value between 80 to 100 for Correctly Classified Instances is usually accepted.

2) Confusion matrix: Confusion matrix also generates according to the Correctly Classified Instances and Incorrectly Classified Instances. The matrix size depends on the number of options in the output class. For example, if the output class has only two options then it generates a 2 by 2 matrix.

$option\_1$	$option\_2$	
a	b	$option\_1$
c	d	$option\_2$

In here,

a + d = value of Correctly Classified Instances

b + c = value of Incorrectly Classified Instances

3) Kappa statistic: This is also a good measurement to check the accuracy of the model. Simply it shows the accuracy of classifying into the correct class when considering any random data point. This value is generated by matching expected accuracy with observed accuracy. The following formula uses to calculate the kappa statistic.

$$\text{kappa statistic} = \frac{\text{observed accuracy} - \text{expected accuracy}}{1 - \text{expected accuracy}} \quad (1)$$

This statistic is used for the model evaluation as follows:

- Kappa statistic < 0 means there is no agreement with accuracy.
- 0 < kappa statistic < 0.20 means that the accuracy is slight.
- 0.21< kappa statistic < 0.40 means that the accuracy is fair.
- 0.41< kappa statistic < 0.60 means that the accuracy is moderate.
- 0.61< kappa statistic < 0.80 means that the accuracy is substantial.
- 0.81< kappa statistic <1 means that the accuracy is perfect.

4) TP rate: This means True Positive rate and it is also a numerical value. It gives how many positive instances are correctly classified into the classes. The following formula uses to calculate the TP rate.

$$\text{TP rate} = \frac{\text{True positive instances}}{\text{Total number of positive instances}} \quad (2)$$

5) FP rate: Opposite of the TP rate. This means a False Positive rate and it is also a numerical value. It gives how many negative instances are incorrectly classified into the classes. The following formula uses to calculate the FP rate.

$$\text{FP rate} = \frac{\text{False positive instances}}{\text{Total number of negative instances}} \quad (3)$$

6) Precision: This talks about how many selected items are relevant to the given class. It shows a proportion of instances that are truly inside the class. The value can take by using the following formula.

$$\text{Precision} = \frac{\text{True Positive}}{\text{True Positive} + \text{False Positive}} \quad (4)$$

7) Recall: This talks about how many relevant items are selected in the given class. It shows the proportion of instances that are classified inside the class. The value is derived by using the following formula.

$$\text{Recall} = \frac{\text{True Positive}}{\text{True Positive} + \text{False negative}} \quad (5)$$

8) F-measure: This is a value that is taken by considering precision and recall. It shows the connection between the low false positives and the low false negatives. Therefore, it is better to get a value near 1 for this and if you take a value near 0 then the model is quite bad. The following formula determines F-measure.

$$\text{F} - \text{measure} = \frac{2 \times \text{Precision} \times \text{Recall}}{\text{Precision} + \text{Recall}} \quad (6)$$

9) ROC Curve/AUC: The Receiver Operator Characteristic curves are commonly used to graphically show the relation between TP rate and FP rates for every possible cut-off test or a combination of tests. An important parameter associated with ROC curves is AUC that stands for Area Under Curve. The classifiers usually take an AUC value between 0.5 and 1.0 where 0.5(random guessing) is considered as worst and 1.0 is the best.

D. Generation of Training and Testing Dataset

Dividing the dataset into training and testing data can be done as shown in Fig. 4. The training dataset takes 2/3 of the total dataset and the testing dataset takes 1/3. All of these two datasets contain “SH” type people as well as people whose health state=“H” and health state = “UH”. Here the health state = “H” group contains both “SH” type people and the people who have become healthy without considering the total WBC’s standard hematology reference value. These notations were introduced and described under Data Preparation in Section III.

E. Experiment Results

Classification algorithms are applied to the dataset with training controls, holdout (using given training/testing dataset), and 10-fold cross-validation to find the best outcome. Table I shows the parameter measures needed to check the accuracy of the model for the training dataset.

The model built by the Random Forest algorithm using the training dataset and the model built by the Random Tree using the training dataset showed the highest number of correctly classified instances and the lowest number of incorrectly classified instances.

When considering the Kappa Statistic, the model built by the Random Forest algorithm's kappa statistic value is higher than the model built by the Random Tree algorithm's kappa statistic value. Therefore, the Random Forest Tree algorithm outperforms all the other algorithms.

The detailed experiment results of the RFT algorithm is given in Fig. 5. As depicted in Table I and Fig. 5, the model built by the Random Forest algorithm with the training dataset has the highest TP rate for both healthy and unhealthy classes. The weighted average of the TP rate and FP rate of this model are 0.915 and 0.279 respectively. The weighted average value for the precision and recall are 0.911 and 0.815, respectively.

F-measure value is an important value when considering the accuracy of the model. The F-measure value for healthy and unhealthy instances is 0.738 and 0.949, respectively. The weighted average is 0.911 which is close to 1.

As shown in Fig. 5, the Confusion Matrix of Random Forest summarizes that 48 healthy instances are classified as healthy, 24 healthy instances are classified as unhealthy, 318 unhealthy instances are classified as unhealthy and 24 unhealthy instances are classified as healthy.

The AUC curves drawn to the Random Forest models for both unhealthy and healthy instances are shown in Fig. 6 and Fig. 7, respectively. AUC values of it for both healthy instances and unhealthy instances give the same value of 0.971. Both curves have deviated much far from the diagonal line close to 1.0.

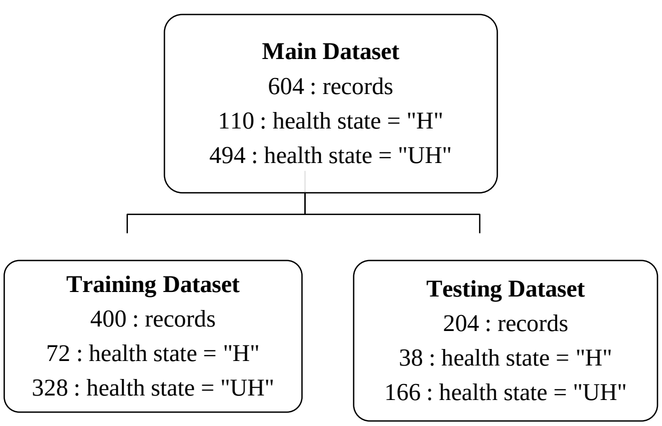
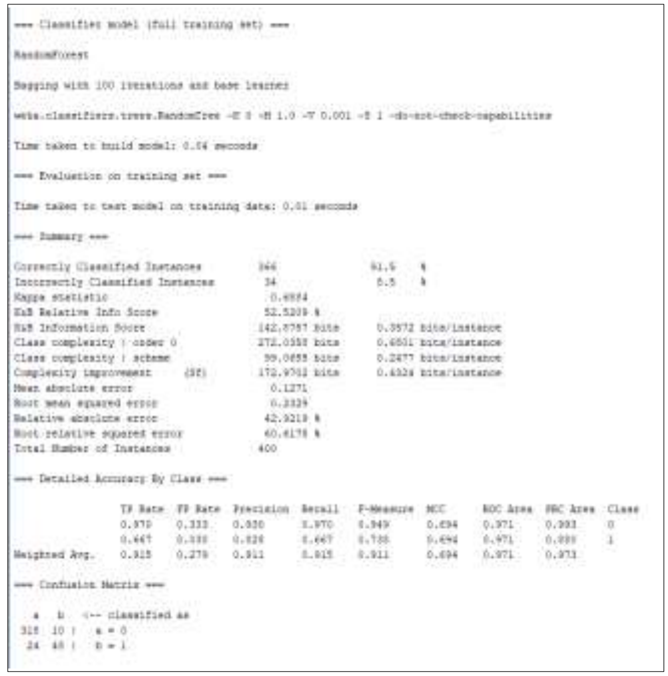


Fig. 4. Training Dataset and Testing Dataset.



```
=== Classifier model (full training set) ===

RandomForest

Bagging with 100 iterations and base learner

weka.classifiers.trees.RandomTree -K 0 -M 1.0 -V 0.001 -S 1 -do-not-check-capabilities

Time taken to build model: 0.04 seconds

=== Evaluation on training set ===

Time taken to test model on training data: 0.01 seconds

=== Summary ===

Correctly Classified Instances        366               91.5    %
Incorrectly Classified Instances       34                8.5    %
Kappa statistic                         0.6884
K&B Relative Info Score                52.5209 %
K&B Information Score                 142.8787 bits      0.3572 bits/instance
Class complexity | order 0            272.0358 bits      0.6801 bits/instance
Class complexity | scheme              99.0655 bits      0.2477 bits/instance
Complexity improvement     (Sf)       172.9702 bits      0.4324 bits/instance
Mean absolute error                     0.1271
Root mean squared error                 0.2329
Relative absolute error                42.9218 %
Root relative squared error            60.6178 %
Total Number of Instances             400

=== Detailed Accuracy By Class ===

               TP Rate  FP Rate  Precision  Recall   F-Measure  MCC      ROC Area  PRC Area  Class
               0.970    0.333    0.930      0.970    0.949      0.694    0.971     0.993     0
               0.667    0.030    0.828      0.667    0.738      0.694    0.971     0.888     1
Weighted Avg.  0.915    0.279    0.911      0.915    0.911      0.694    0.971     0.973

=== Confusion Matrix ===

   a   b   <-- classified as
 318  10 |   a = 0
  24  48 |   b = 1
```

Fig. 5. The Experiment Results of the RFT Algorithm.

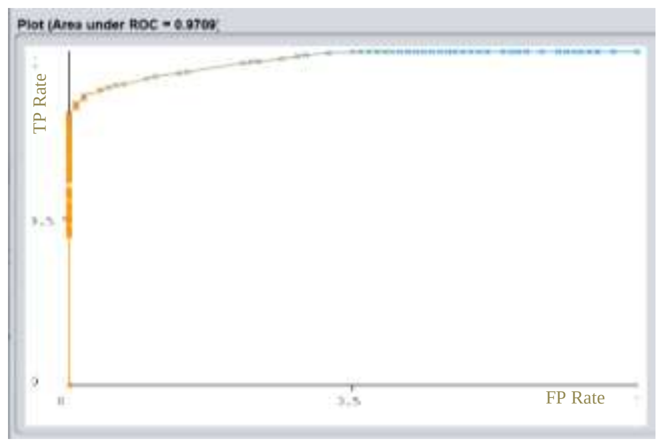


Fig. 6. ROC Curve for unhealthy Instances in the Model Built by using the Random Forest Algorithm.

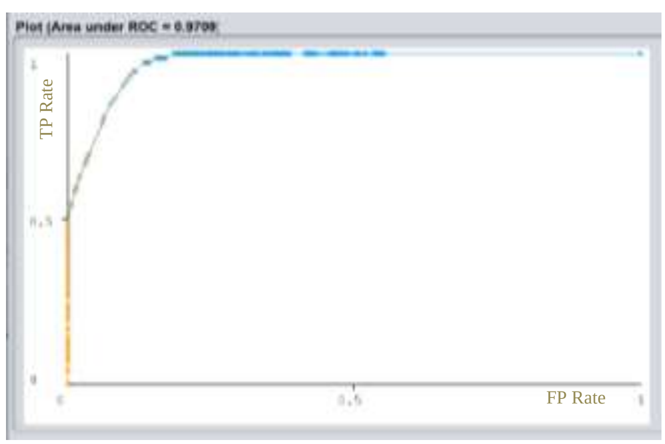


Fig. 7. ROC Curve for Healthy Instances in the Model Built by using the Random Forest Algorithm.

TABLE I. ACCURACY FEATURES

Algorithm	Correctly classified	Incorrectly classified	Kappa Statistic	Class attribute	TP Rate	FP Rate	Precision	Recall	F-measure	AUC
RFT - training dataset	366	34	0.6884	H	0.667	0.030	0.828	0.667	0.738	0.971
				UH	0.970	0.333	0.930	0.970	0.949	0.971
RFT – 10 folds CV	331	69	0.3563	H	0.403	0.079	0.527	0.403	0.457	0.854
				UH	0.921	0.597	0.875	0.921	0.897	0.854
RT - training dataset	366	34	0.6648	H	0.583	0.012	0.913	0.583	0.712	0.972
				UH	0.988	0.417	0.915	0.988	0.915	0.972
RT – 10 folds CV	326	74	0.2705	H	0.306	0.073	0.478	0.306	0.373	0.739
				UH	0.927	0.694	0.859	0.927	0.891	0.739
REP - training dataset	351	49	0.5139	H	0.472	0.034	0.756	0.472	0.581	0.917
				UH	0.966	0.528	0.893	0.966	0.928	0.917
REP - 10 folds CV	329	71	0.2160	H	0.208	0.043	0.517	0.208	0.297	0.844
				UH	0.957	0.792	0.846	0.957	0.898	0.844
LMT- training dataset	347	53	0.5437	H	0.611	0.076	0.638	0.611	0.624	0.925
				UH	0.924	0.389	0.915	0.924	0.920	0.925
LMT - 10 folds CV	332	68	0.3541	H	0.389	0.073	0.538	0.389	0.452	0.885
				UH	0.927	0.611	0.874	0.927	0.899	0.885
J48 - training dataset	357	43	0.5840	H	0.542	0.030	0.796	0.542	0.645	0.931
				UH	0.970	0.458	0.906	0.970	0.937	0.931
J48 - 10 folds CV	330	70	0.3099	H	0.333	0.067	0.522	0.333	0.407	0.851
				UH	0.933	0.667	0.864	0.933	0.897	0.851
HT - 10 folds CV	327	73	0.1456	H	0.139	0.034	0.476	0.139	0.215	0.670
				UH	0.966	0.861	0.836	0.966	0.897	0.670

IV. RESULTS AND EVALUATION

The model built by using the Random Forest algorithm was used to evaluate the test dataset and the results of it are shown in Fig. 8. As similar to the results for the training dataset described in Fig. 5, the results for the test dataset have also shown the excellent performance of RFT with the low variance.

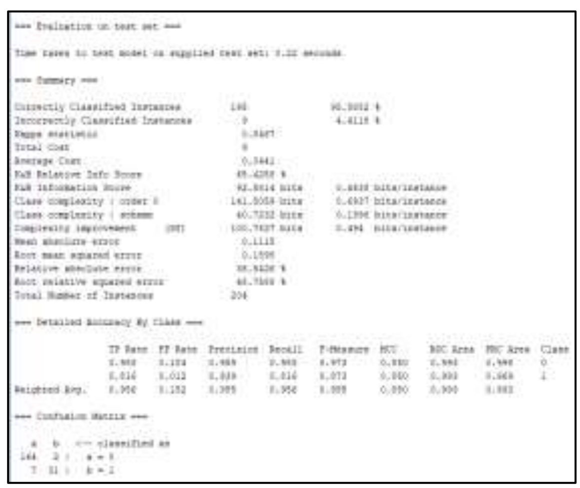
As depicted in Fig. 4, there are 38 healthy instances and 166 unhealthy instances. The confusion matrix shown in Fig. 8 shows that the deviation of TP and TN values from the actual is very much low.

An estimation of the local reference range of WBC is determined based on the values of WBC of the healthy instances predicted by the RFT algorithm. The manual inspection of those healthy instances shows that WBC values lie within the range of 4100mm^3 – 12800mm^3. When compared with the standard reference range of WBC shown in Fig. 9, it can be observed that the local reference range of WBC is not the same as the standard reference range.

Some local WBC reference ranges which were established in other countries are as follows.

- 4420mm^3 – 11100mm^3 in Estern India [2].
- 2900mm^3 – 9600mm^3 in Sudan[1].
- 1900mm^3 – 10100mm^3 in Togo [9].
- 2800mm^3- 7200mm^3 in Malawi [5].

The above ranges have differed from the standard WBC reference range as well as our result. The nutrition levels in African countries may cause to return very lower boundary value for WBC. Sri Lanka is in a better state when compared with the African countries regarding nutrition levels. Hence the received range for WBC is reasonable.


=== Evaluation on test set ===

[illegible]

=== Summary ===

[illegible]

=== Detailed Accuracy By Class ===

[illegible]

=== Confusion Matrix ===

[illegible]

Fig. 8. ROC Outcome of the Test Dataset-RFT.

Haematology Normal Adult Reference Ranges	Male	Female	Units
Haemoglobin (HB)	130-180	115-165	g/L
White Cell Count (WBC)	4-11	4-11	10^9/L
Platelet Count (PLT)	150-450	150-450	10^9/L
Red Blood Count (RBC)	4.5-6.5	3.8-5.8	10^{12}/L
Mean Cell Volume (MCV)	80-100	80-100	fl
Packed Cell Volume (PCV)/Haematocrit (HCT)	0.40-0.52	0.37-0.47	L/L
Mean Cell Haemoglobin (MCH)	27-32	27-32	pg
Mean Cell Haemoglobin Concentration (MCHC)	320-360	320-360	g/L
Neutrophil Count	2.0-7.5	2.0-7.5	10^9/L
Lymphocyte Count	1.5-4.5	1.5-4.5	10^9/L
Monocyte Count	0.2-0.8	0.2-0.8	10^9/L
Eosinophil Count	0-0.4	0-0.4	10^9/L
Basophil Count	0-0.1	0-0.1	10^9/L

Fig. 9. Standard Hematology Reference Ranges (https://www.royalwolverhampton.nhs.uk/services/service-directory-a-z/pathology-services/departments/haematology/haematology-normal-adult-reference-ranges/).

V. Conclusion

Medical Science is an immense area. Day by Day the area is updated. This research relates to Medical Science which spans across a vast area covering many disciplines and gets updated daily. The whole research was run based on certain disciplines such as Hematology, healthiness, unhealthiness, etc. The concept “healthy” is very complicated to define in medical science. It does not have a simple idea. It can be defined by using various subcategories. Hematology is such a subcategory. Medical officers may identify a person as healthy by looking at his blood reports. But it may not be correct as there will be a person with a good blood report but with disabilities on eye, ear, etc., inappropriate living styles like food habits, exercise habits, alcohol addictions, etc., diseases that cannot be detected from blood reports, or else everything is good but not healthy in mentally. Therefore, healthiness may not be determined always from the blood reports.

However, assuming that if a person is suffering from a disease, medical officers often check the blood reports to detect the disease, Hematology science is very helpful in such kinds of scenarios. This small area was addressed only through this research which assumes the healthiness depends only according to the blood reports.

The outcome of this research is to determine a local hematology reference range using data mining and machine learning techniques and the selected dataset was belongs to the adults in Sri Lanka. The research focused on finding a local reference range for total WBC value only. Hence a local reference range for the total WBC value was determined. The standard WBC (leukocyte) referential range is 4000mm^3 – 11000mm^3 and the local reference range which was empirically determined as the result of this research was 4100mm^3 – 12800mm^3. By repeating the same experiment for several different datasets and taking the average of the results, the accuracy of the local reference range can be further improved. And the proposed framework for WBC can be used to determine the local hematology reference ranges for other Hematology tests as well.

When considering the similar works discussed in Section II, most of the researchers who tried to establish local hematology reference ranges for their countries have used statistical approaches. The drawbacks of statistical approaches have been discussed in Section II. The proposed approach using data mining and machine learning concepts is the best solution to address all mentioned drawbacks. It does not depend on data distributions or the number of data records. Also, data mining and machine learning concepts perform well with the fair representation of the sample dataset.

There are several limitations in this research. The data used for the research belongs to people over 21 years old. The dataset has been taken from hospitals, laboratories in a particular area and hence does not cover the whole area of Sri Lanka. Further, the accuracy of the dataset plays a vital role in this nature of the research. In this regard, a carefully set up survey can be conducted to obtain blood samples from selected donors. Despite the set setup is not straightforward and involves high cost, the following suggestions are recommended in selecting the donors.

- Should cover different geographical areas, climate zones, cultural backgrounds, etc. in Sri Lanka.
- Use the medical history of the donors to categorize them as healthy or not.
- Incorporate the food habits, living styles, disabilities, BMI index, smoking habits, alcohol consumption, sexual diseases, etc. too to determine the healthiness of the donors.

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A WSM-based Comparative Study of Vision Tracking Methodologies

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***Abstract*—Vision tracking is a key component of a video sequence. It is the process of locating single or multiple moving objects over time using one or many cameras. The latter's function consists of detecting, categorizing, and tracking. The development of the trustworthy solution for video sequence analysis opens up new horizons for a variety of applications, including intelligent transportation systems, biomedical, agriculture, human-machine interaction, augmented reality, video surveillance, robots, and many crucial research areas. To make efficient models, there are challenges in video observation to deal with, such as problems with the environment, light variation, pose variation, motion blur, clutter, occlusion, and so on. In this paper, we present several techniques that addressed the issues of detecting and tracking multiple targets on video sequences. The proposed comparative study relied on different methodologies. This paper's purpose is to list various approaches, classify them, and compare them, using the Weighted Scoring Model (WSM) comparison method. This includes studying these algorithms, selecting relevant comparison criteria, assigning weights for each criterion, and lastly computing scores. The obtained results of this study will reveal the strong and weak points of each algorithm mentioned and discussed.**

Keywords—Multiple object tracking; object detection; WSM method; computer vision; video analysis

I. Introduction

Target/Object tracking is the challenge of determining the location, path, and attributes of objects of interest using sensor measurements [1]. A sensor could be any measuring equipment that collects information about targets in the environment, such as sonar, radar, infrared sensor, lidar, camera, ultrasound, microphone, or any other sensor. Object tracking is common goals include determining the number of targets, their states, and their identities, such as velocities, positions, and in certain situations their features. The radar monitoring of aircraft is a typical example of target/object tracking.

Based on measurements collected from radar, the object tracking issue, in this case, aims to determine the number of aircraft in a surveillance area, their types, such as commercial, military, or recreational, their speed, and their identities and positions. The object tracking problem contains a variety of sources of uncertainty, making it a difficult undertaking. Object motion, for example, is frequently subject to random disruptions; sensors could misdetect objects, and the number of objects/targets in a sensor's field of view could change at random. Sensor measurements are prone to random disturbances, and the number of measurements acquired by a sensor could vary and be unpredictable from one look to the next. Objects may be closer, and the measurements acquired may not be able to distinguish among them properly. Sensors could offer data even when there is no object in the area of view.

Humans could track objects visually with relative ease. However, it is not obvious, and it is difficult for a computer to track a moving object under illumination variation, with different shapes and format, object-to-scene and object-to-object occlusions, as well as background, clutters, and with several appearances in-camera projective space, object appearance, and object disappearance. Multiple object tracking is a set of tasks to reach tracking starting from object detection, object classification then objects tracking. Tracking objects is following their trajectory with video and their different positions within frames. Lastly, Multi-object tracking or multi-target tracking is gaining widespread interest across different research areas ranging from autonomous cars and vehicles, video surveillance, human-machine interaction, virtual environment, biomedical analysis, and so on. These objects may be pedestrians, cars, fish, vehicles, motorcycles. Although object tracking has a wide range of areas, it is still suffering from problems that we are going to discuss carefully in the next coming sections. Most of the researchers are trying to tackle these challenges carefully; however, some of them fail to solve some of the obvious problems. That is why we are offering you this comparative study that aims to identify, analyze, and compare the different object tracking methods.

As a result, this work provides a weighted scoring model (WSM)-based comparison evaluation of different methodologies. Our comparative study begins with the extraction of crucial criteria for comparison and a description of each criterion (Section 5). These criteria have been gathered from relevant work comparative research (Section 3) in addition to some other criteria that are missed. The WSM approach is then used to calculate final scores for each algorithm, which requires weight attribution (Section 5). The results are depicted as a chart and carefully discussed (Section 6).

II. Related Work

Many scientific studies have been conducted to develop multi-object tracking systems and applications based on a wide range of algorithms of the deep learning era and other eras. Many researchers and scientists have put up scientific efforts in this direction to apply several algorithms. The authors provide solutions in a variety of areas, including Smart City, Smart Vehicle, Industry, logistics, medical, surveillance, etc.

Several studies have compared multi-object tracking methods relied on different methods and directions. Each comparative study has its uniqueness and crucialness.

In [2], the authors picked up just three algorithms (Extended Kalman Filter [3], Gaussian mixture model GMM [4], and Mean Shift Algorithm [5]) and compared them. On the one hand, resulting in that GMM performs better when there is occlusion, contrary to Extended Kalman filter. On the other hand, the mean shift algorithm is best suited to single target tracking, at meanwhile, the results reveal that this approach is unable to detect many objects when even minor occlusion exists.

In [6], the authors are comparing multi-object tracking methods for sports events, choosing four algorithms; namely, Medianflow [7], boosting[8], multi-instance learning(MIL) [9], Kernalized correlation filter (KCF) [10], measuring as well as comparing their performances. Resulting from that the tracking of the object is efficient if the object's movement is constant when utilizing the MEDIANFLOW[7] algorithm. However, if the object's movement suddenly changes, it will be unable to follow the trajectory. For tracking many items in a sporting event, the KCF [11]algorithm, performed best, boosting had a greater tracking success rate than MIL, and it tracked roughly 5 times faster.

In [12], the authors are including an examination object detection method, object representation, and feature selection, and object tracking over many frames. By comparing seven different techniques (Kalman Filter[13], Particle Filte[14]r, Mean shift [7], CamShift[15], KLT tracker[16], template matching[17], Contour Tracking [18]) relied on number of object tracked, occlusion handling, optimal or not. Resulting from that Kalman Filter, KLT tracker, Particle Filter, Contour Tracking is handling occlusion and they are optimal strongly the last two ones could strongly track multiple objects.

In [19], the authors are presenting a paper that provides a brief overview of the numerous object detections, categorization, and tracking algorithms in the literature, as well as analysis and comparison of the many strategies utilized at various phases of tracking; reaching a comparison of the different techniques Point-Based Tracking, Kernel-Based Tracking, Silhouette Based Tracking. Concluding that single object tracking provides good accuracy for many types of movies with varying conditions, such as low resolution or weather changes.

In [20], the authors wrote a comparative examination of multiple vision tracker categories is conducted by the work to determine which one is the most successful in tracking construction resources. The benefits and limits of each kind of tracker are discussed, as well as the testing procedures for evaluating them. The methods are divided into the same categories used in the previous paper. The kernel-based ones are insensitive to illumination conditions and scale variation than point tracking-based methods as well as point tracking are effective under occlusion.

In [21], on the one hand, the authors examine various object tracking techniques in this research. The classification of these techniques is the same classification as in the previous papers kernel, silhouette, and point tracking-based. Their comparison is based on a wide range of criteria, concluding that point tracking methods are dealing better with occlusion; meanwhile, they are optimal. On the other hand, they present the advantage and the limitation of the different existing methods.

In [22] authors discuss Background subtraction, template matching, Frame difference, and shape-based approaches that are some of the most frequent approaches used in object tracking. In addition, they talk about topics like detection and tracking. At the end of this review on object detection and tracking methods, they summarize a table containing the advantages and disadvantages of usual object tracking methods. Concluding that the best method of object vision tracking vision is by combining different methods at the same time.

In [23], this comparison is evaluating 2D to 3D vision tracking method's performance, reaching a comparison also for the usual sub-categories kernel object tracking, point object tracking, silhouette object tracking. Concluding that the first findings of this comparison indicate that of the two types of trackers examined for construction-related applications, kernel-based approaches are more trustworthy.

In [24], the authors present a review of the existent approaches of moving object detection, their Challenges, and mentioning object tracking at the end. The object tracking methods that are mentioned in this article are Mean-shift, KLT, Condensation [25], TLD, Tracking Based on the Boundary of the Object. Mentioning that, TLD [26] is an award-winning, real-time method for tracking unknown objects in a video sequence.

III. Background

A. Vision Tracking

The difficulty of determining the trajectory of an object in the image plane as it moves across a scene is known as tracking. Various ways of tracking the object include kernel tracking, point tracking, and silhouette tracking.

Various ways of tracking the object include point tracking, kernel tracking, and silhouette tracking. The following categories could be used to categorize cribbed tracking methods.

Because of the enormous variety of applications and the high-performance of vision tracking in many fields, object tracking has sparked a lot of interest and attention in the field of computer vision. Two key stages must be completed in order to achieve vision tracking. The initial stage is to detect targets of interest, which could be done either automatically or manually depending on the approach used. The second stage, also known as target localization, involves following the discovered objects and predicting their changes in terms of position and form in subsequent image frames.

B. Target/Object Tracking Methods

As mentioned in Fig. 1 there are three main subclasses of object tracking [1]:

- Point tracking.
- Kernel tracking.
- Silhouette tracking.

Table I is summarizing an overview of object tracking methodologies their main goal, their advantages, their disadvantages, and some of their methods. Additionally, Table II illustrates the advantages and limitations of object tracking methodologies.

1) Silhouette based tracking approach: Because of their irregularity, many sorts of objects could not be successfully represented using simple geometric shapes due to their complexity. Silhouette-based approaches give a precise form description for different objects'/targets' shapes. Heads, hands, and shoulders are examples of composite shapes that are difficult to characterize with geometric geometry or shapes, that is what this category is made for; in other words, to shape non-geometric shapes. A suitable geometric shape for those objects/ targets will be given by this methodology. The main goal of this mechanism of tracking is to detect the target region in each frame using the assistance of a target model outputted from previous frames. It is possible to deal with a variety of object shapes, object split and merge and occlusions. The model is represented by object edges, a color hologram, or a contour. Shape matching and contour tracking are the two types of silhouette tracking that we use. These techniques are capable of handling a variety of problems such as it could be used to manage a wide range of objects of various shapes means dealing with a wide range of target's shape, and it also handles occlusion, silhouette tracker may split and merge objects as well. This silhouette-based tracking could be divided into two main categories, i.e. contour-based tracking approaches and shape matching tracking approaches.

a) Contour Tracking: Iteratively evolving an initial contour based on object placement in previous frames to a new place in the current frame is how this strategy works. Object portions in the current frame must overlap the object in the previous frame for the contour to evolve. When tracking is based on contour evolution, two ways could be used. State-space models, which are utilized for motion and contour shape modeling, are used in the first method. The other technique generates the contour directly by using direct minimization methods to reduce contour energy. Consider gradient descent, one of the most appealing aspects of this approach is its ability to handle a wide range of object shapes. The silhouette could be represented intuitively by a function defined on a grid, and it could also be expressed clearly by a set of control points to indicate its border.

b) Shape Matching: In the kernel technique, shape matching performs similarly to template-based tracking. Another method for Shape matching is to look for silhouettes that are similar in two consecutive frames. The process of silhouette matching is similar to that of point matching. Background subtraction is used to conduct Silhouette detection. Density functions, silhouette boundaries, and object edges make up the Models object. Hough transform techniques will be used to handle occlusion and dealing with a single object.

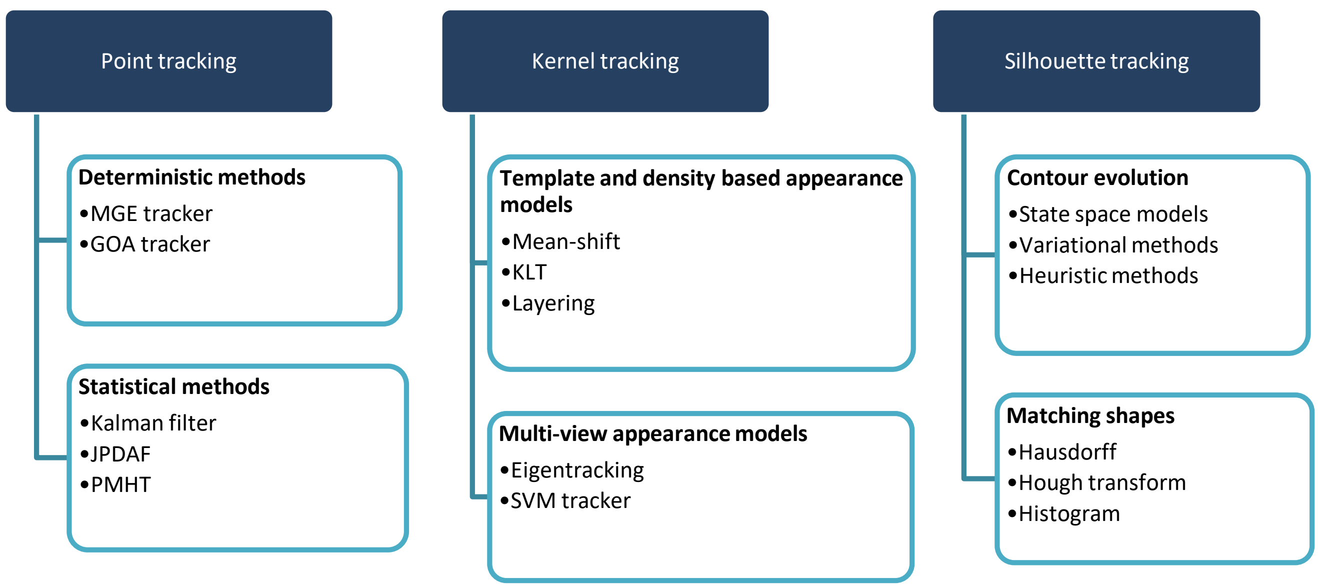

Fig. 1. Object Tracking Main Methodologies [1].

TABLE I. OBJECT TRACKING METHODS

	Kernel tracking		**Silhouette tracking**		**Point Tracking**	
Main goal	Estimating object motion		Tracking exact contour		tracking small objects	
Advantages	handling occlusion		Ability to represent a wide range of shapes, handle a large variety of object shapes		tracking small objects	
Disadvantages	handling multiple objects		handling occlusion and object merge and split		Handling occlusion at the meanwhile appearance and re-appearance	
Categories	Template based models	Multi-view models	Contour evolution	Matching Shapes	Deterministic	Statistical
Some of the methods	Mean-shift	SVM Tracker	Variational methods	Histogram	MGE Tracker	MHT filter

TABLE II. ADVANTAGES AND LIMITATIONS OF OBJECT TRACKING METHODS

Tracking Methods	**Advantages**	**Limitations**
Kalman Filter	. Capable of tracking pictures that are noisy. We could not rely on the average of past values if our sensors deliver incorrect data or if they do not produce any data at all for a certain time. Outliers are dealt with the use of Kalman filter. . Work for linear models and Gaussian distribution.	. Kalman filter is unusual for non-gaussian problems.
Particle Filter	. An efficient algorithm used in the world of non-gaussian and non-linearity. In addition to the capability of multi-modal filter that why it is widely used. . Particle filter methods are extremely adaptable, simple to develop, parallelizable, and suitable in a wide range of applications.	. Particle filters do not have a strict proof of convergence
Mean shift	. When there are a lot of colors, this is a good option.	. Could not be applied in the case of complex scenes.
KLT tracker	. Handle Occlusion	. Multiple object tracking this method Becomes complex.
Template matching	. It is a lot easier to set up and utilize.	. A slow method for recognizing new variations of a pattern. · It only works if the object is always visible in the video; else, false detects will occur. . When there are a lot of objects/targets, it is difficult to keep track of them all. . Complex templates are not recommended. . When items leave the frame or become occluded, problems could arise.
Contour Tracking	. Complex models for non-rigid and rigid objects could be highly handled. . Illumination levels do not have a high impact	. It is difficult to deal with entry objects.

2) Kernel-based trackers: Kernel-based tracker utilizes representations and appearance of the object/target of interest using ellipsoidal or rectangular shapes. It is possible to track a target or an object by tracking the motion of each kernel on the associated frame. The motion of a target or an object could be classified in different ways including rotation, translation, or transformation. The motion of an object could be categorized in different ways including affine transformations, rotation, and translation. Several algorithms could be utilized for this goal, which differs relying on the quantity of target tracking, object motion method, or object representation. For instance, in real-time applications, geometric shapes are frequently used to represent objects. One disadvantage of employing geometric shapes is that they may not completely encapsulate the target object, allowing background objects to be visible. The mean shift method, template matching, and CAMShift tracking are some available approaches that could be used for kernel tracking, relied on Kernel tracking methodology.

a) Simple Template Matching: Template matching is a computer vision program that finds related objects in photos. For mapping similar patterns between images, template matching is an important part of the image analysis process. Image processing is a computer-assisted technique for analyzing and manipulating images. It is mostly used to enhance the quality of an image, as well as to detect and highlight specific areas of the image. Image processing techniques are primarily used to improve the quality of an image and perform feature extraction and classification for a variety of purposes. In the automation process, template matching is used to recognize objects and improve the quality of the searching process. It is used to locate the target item from an image in astronomy, meteorology, medical imaging, remote sensing, and many other related domains. It is an image processing approach in which a specific object is chosen as a target, to be recognized and mapped to the original image. For images matching, a variety of techniques are utilized, with Edge-based matching and Greyscale-based matching being the most popular. Greyscale-based is an extension of correlation-based that works regardless of the orientation of the image. The greyscale-based technique recognizes both the template location and orientation, allowing us to recognize images from a variety of angles. Edge-based matching is similar to greyscale matching, except that instead of computing the entire image, only the edges of the image are recognized and matched with surrounding pixels.

*b) Mean Shift Method:*This tracking method utilizes density-based appearance models to describe a target. A histogram is used to represent the appearance model (color, texture) within this algorithm. This method employs an iterative tracking approach, which entails identifying similar pattern distributions within a sequence of frames.

c) Support Vector Machine (SVM): SVM is a general classification approach that uses a set of positive and negative sample values to define it. Positive samples containing tracked visual objects are used in SVM.

The negative samples are made up of everything else that isn't being tracked. It could handle a single picture as well as partial occlusion of an object, although physical initialization and training are required. SVM finds the best separating hyperplane between two classes. In SVM as a tracker, the positive examples for SVM-based trackers are photos of the object to be tracked, while the negative examples are those objects that are not to be tracked. Negative examples are typically made up of background regions that could be mistaken for the object.

d) Layering based tracking: Multiple objects could be tracked using this kernel-based tracking approach. Each layer has an elliptical form, motion (such as translation and rotation), and layer appearance (based on intensity). Layering is accomplished, first by accounting for background motion such that the object's motion may be calculated using 2D parametric motion from the rewarded image.

3) Point-based trackers: It is a common computer vision task with a wide range of applications. During tracking, moving objects are carefully represented as feature points in an image structure. Point tracking is a difficult problem, especially when occlusions occur. Point Tracking could handle the following situations, suitable for tracking extremely small objects. Objects identified in successive frames are represented by points, which are linked together based on the prior object state, which could include object position and motion. This method necessitates the use of an external system to detect the objects in each frame.

These are the main point-based trackers' methods:

a) Kalman Filter: This is one of the most used techniques of point-based trackers [27]. In a real-world scenario where we are tracking a moving object from our car or vehicle, we could not rely on the average of prior values if our sensors transmit incorrect data or if they do not send any data at all. Outliers are dealt with with the use of the Kalman filter. It only evaluates one sensor data at a time and compares it to prior values, giving the previously estimated measurement more weight if it has a low error and giving the newly taken value from the sensor more weight if it has a low error. Because it only analyzes a proportion of newly taken value at each time step, it avoids the problem of outliers. Well, the Kalman filter is used to anticipate most measurements where we acquire data from hardware, such as sensors, and we do not know how reliable the data is. The Kalman filter algorithm could be broken down into the following steps:

1) Initialize state and covariance matrices: When we receive the first sensor measurements, we initialize the state (position and velocity) of the moving target, such as a bicycle.

2) Forecast step: Based on certain prior data and the model, we produce a state prediction.

3) Step of updating: The predicted and measured locations are merged to produce an updated location. Depending on the uncertainty of each number, the Kalman filter will give greater weight to the projected or observed location.

4) The process is repeated as the automobile receives new sensor readings. They have relied on the algorithm of Optimal Recursive Data Processing.

b) Particle Filter: The versatility of particle filter technology is due to its efficiency in nonlinear and non-Gaussian systems. Furthermore, the particle filter's multi-modal (we want to track, simultaneously, zero, one, or more than one object) processing capabilities is one of the reasons for its widespread use. Particle filtering has been used in a variety of fields around the world. It is based on the Markov Chain Monte Carlo improvement strategy, by generating Markov chains with good convergence; the approach generates samples from the target distribution. Particle filter methods are extremely adaptable, simple to develop, parallelizable, and suitable in a wide range of applications. The particle filter method can handle different problems such as occlusions.

c) Multiple Hypothesis Tracking (MHT): Several frames have been detected in the MHT algorithm for better tracking results. The MHT algorithm is an iterative process. Each Iteration starts with a set of track hypotheses that already exist. Each theory is made up of a group of disconnected tracks. A prediction of the object's position in the next frame is made for each hypothesis. Then, the predictions are compared, using a distance metric. The MHT could track several objects, deal with occlusions, and calculate optimal solutions. The algorithm can create new tracks for objects entering the field of view FOV and terminate tracks for objects exiting the field of view FOV.

C. Research Areas

Due to the existence of several objects in our lives, for instance, humans being (pedestrians [28], sport players [6], shoppers), vehicles (cars [29], motorcycles, buses), animals (fishes [30], birds [31], cats), other (cells [32], insects), and so on; many scientific studies have explored implementing multiple object tracking using different algorithms. These initiatives are divided into research areas or domains; see Fig. 2, such as:

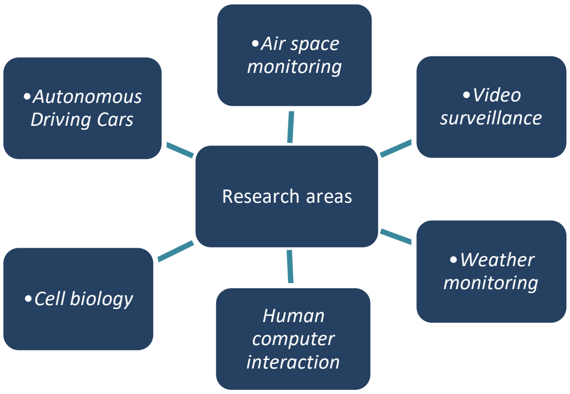

Fig. 2. Some Research Areas of Object Tracking.

- *Air space monitoring*: The tracking of aircraft using radar is a serious and crucial issue [33], for instance, air traffic control. Radar tracking is employed also in military surveillance systems to identify aircraft: identity, type, location, speed, and the item's potential intents to establish, for instance, if the object is a threat. Radar is capable of a wide range of observations, from high range measurements to simple-resolution imaging. Radar [34] utilizes radio waves to determine the object's distance, direction, and radial speed.

- *Video surveillance: Surveillance* [29] using digital video is becoming increasingly popular. Airports, banks, casinos, highways, stadiums, crowd gathering areas, buildings, streets, railway stations, department stores, and all government organizations now use video surveillance to reinforce their security. Video surveillance is employed in almost every aspect of society to deter criminal activity and improve public safety and security [35]. A large typical building in a major city has a vast network of cameras installed on main floors, entrances, huge gathering areas, hallways, offices, and labs.

- *Weather monitoring*: Weather bureaus employ a variety of approaches to give weather forecasts [36]. Tracking weather balloons, which offer data on high-altitude wind velocity, humidity, pressure, and temperature, is a widely used method. Each day, weather bureaus released 50 to 70 balloons at various times throughout the day. The frequency of releases rises during extreme weather because more data is required for good weather forecasting. Each weather balloon must be tracked to obtain weather-related parameters at various heights of the atmosphere.

- *Cell biology*: Pathologists and medical researchers commonly examine death and birth rates, as well as the mobility of biological cells [37], in research studies of humans, plants, insects, and animals. In immunology, the immune of organism response is linked and correlated with lymphocytes' life cycle. The division/death and birth rates of every generation of cells are the parameters of interest. The velocity or morphology of sperm cells is an interesting metric of infertility study.

- *Autonomous Driving Cars*: The self-driving [38] systems are also known as autonomous cars or driverless vehicles; a car is a vehicle that could sense its surroundings and move in designated lanes without the need for human intervention. In other words, object detection and tracking are required for autonomous vehicles to reliably recognize and localize dynamic targets in the environment surrounding vehicles that contain the tracking system. The principles of developing self-driving automobiles are completely based on perceiving their surroundings and automating tasks.

- *Human-computer interaction*: Gestures [35] have long been thought of as an inter-action approach that may help us communicate with our computers in more creative, natural, and intuitive ways [39]. Many modern apps rely on human-computer interaction are developed. Because of the interest of psychology and cognitive science, for example, understanding user behavior such as body motions, particularly facial expression recognition is one of the main uses of computer vision that are gaining a lot of interest due to its different uses.

- *Augmented reality*: Nowadays, this research area is gaining a crucial and wide range of interest. Augmented reality [40] is the fact of making users in a virtual environment using different virtual objects. By generating perceptual information to enhance real-world objects in a variety of ways, including aural, visual, somatosensory, haptic, and olfactory. Object tracking is implemented in augmented reality to reach sometimes the interaction between objects or targets.

- *Robotic*: Nowadays, this research area is gaining a lot of interest due to its importance in many cases. Robots may replace human tasks by doing these tasks efficiently or sometimes better than humans. Vision tracking is relying on detection or tracking reached by robots [41].

IV. Weighted Scoring Model

The Weighted Scoring Model is a mechanism for comparing objects and picking up between them, based on a set of criteria. The WSM Method is used to compare the algorithms. The application of this strategy could be done in the following steps (Fig. 3):

- Step 1: Determine which criteria will be used to perform each method.

- Step 2: Granting weights to groups of criteria based on the crucialness of each one.

- Step 3: Create a table with nominal values for each criterion of each distribution.

- Step 4: Create a table with weighted values for each criterion. The weight is expressed as a percentage. The overall weight is 100 percent.

- Step 5: A calculation of the product score of weights and nominal values is elaborated for each method.

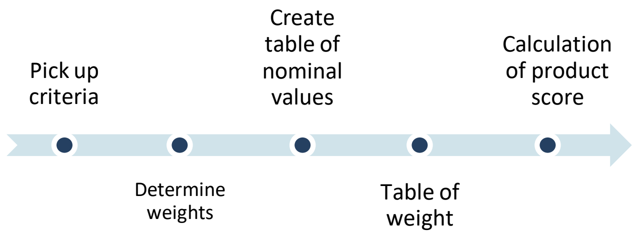

Fig. 3. WSM Process.

V. Comparison of Multiple Object Tracking Methods

A. Comparison Criteria

The comparative criteria were chosen based on several video analysis investigations especially object tracking. Some criteria have been derived from the works cited below. Those are essentially the challenges are mentioned in Fig. 4 that all multi-object tracking methods and algorithms have in common to tackle them or to deal with them:

- *Occlusion*: Occlusion when the target is fully or sometimes partially or occluded. Complex interactions between objects result in both temporally and spatially occlusions, making object tracking a challenging problem [42]. In other words, in complicated scenes and crowded settings, it is common for an object's direction to be obscured, either by a background component such as a stationary scene or by other targets.
- *Illumination variation*: The Illumination in the target area has been changed due to different issues such as obstacles that make birth of shadow, camera position and resolution, and the main source of illumination. Changes in illumination and posture are all essential elements that influence recognition rates, with the effect of light circumstances being particularly crucial. The direction of the light source may cause the image to be excessively bright or too dark, causing the algorithms to have difficulty in accurately obtaining crucial features [43].
- *Clutter*: The background in the vicinity of the target has the same color or texture as the target. A more complex scene results in more detection failures, which include undetected targets (false negatives) or spurious targets (false positives). As a result of the inadequate detection, data association accuracy is not reliable. Most algorithms are aiming at separating the background from targets [44].
- *Enter field of view*: Objects are moving in different directions with different motions. That makes the birth of more objects that enter the field of view and others leaving the field of view, and we are talking about object appearance and object disappearance, two different phenomena within a video for non-rigid objects.
- *Speed*: The motion or speed of the targets/ objects on the ground truth is large. The states of the targets, or their positions, change with time. At first glance, we are unsure about their precise location. However, Things become more complicated when the object's direction changes. Each object has its speed and direction. The model should be able to deal with these fast changes [45].
- *Scale variation*: The bounding boxes shape of the object in different frames is ranging widely. The algorithm or model should be able to track the target from numerous perspectives and scales. One of the reasons for the disparity in performance is the large-scale variation amongst object instances, particularly the difficulty of recognizing very small objects [46].
- *Optimal*: This criterion is defining if the algorithm needs training or not, it needs resources or not.
- *Outlier*: some values are outside the range of what is expected, unlike the other data. We call these values outliers.

B. Comparison Study

Table of nominal values is carried out. For each criterion, the value that corresponds to each method is assigned. These values are extracted from related work.

C. Application of Weighted Scoring Model

The score of each challenge based on its existence is determined using the WSM method, as shown in Table III. The weight percentages are assigned based on the importance of the criterion. This collection of criteria is given priority due to their necessary requirement: number of objects tracked– Enter Field of view – Outlier. A weight of 12% is ascribed to each of their criteria. The following category of crucialness is given to the criteria Scale Variation – Illumination variation – Occlusion. A weight of 10% is ascribed to each of their criteria. And optimal, a weight of 20% is ascribed due to its importance and 14% associated to speed.

By applying the weight scoring model in Table IV, we are going to associate to each value a number relying on its crucialness n/a →0, all the criteria are ranging from 1 to 5, after getting these values we multiple each value by its weight as illustrated in Table III of weights. The result is mentioned in the table.

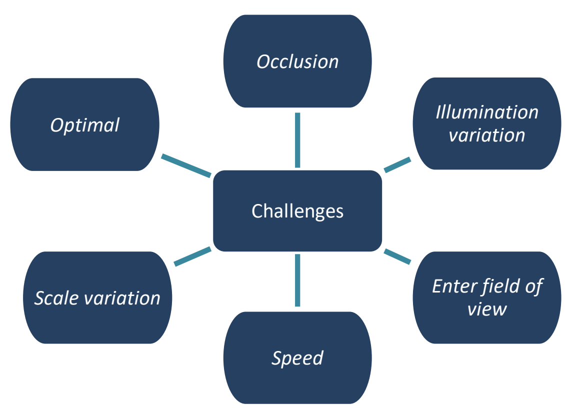

Fig. 4. Some Crucial Challenges of Object Tracking.

TABLE III. ASSOCIATED WEIGHTS TO EACH CRITERION

Criterion	**Abbreviation**	**Proposed weights**
Number of objects tracked	NO	12%
Illumination variation	IV	10%
Occlusion	OCC	10%
Enter Field of view	FOV	12%
Scale Variation	SV	10%
Speed	SP	14%
Optimal	OP	20%
Outlier	OUT	12%

TABLE IV. COMPARISON FOR DIFFERENT OBJECT TRACKING METHODS. (PT: POINT TRACKING, KT: KERNEL TRACKING, ST: SILHOUETTE TRACKING)

	TT	NO	OCC	IV	SP	SV	OP	FOV	OUT
Kalman Filter	PT	1	1	2	3	3	3	2	2
U Kalman Filter	PT	5	2	2	3	4	4	2	4
Particle Filter	PT	5	2	2	3	4	4	3	4
MGE tracker (D)	PT	5	2	1		4	1	2	4
GOA tracker	PT	5	2	2	n/a	3	2	1	n/a
JPDAF	PT	5	2	n/a	n/a	3	1	1	n/a
Multiple Hypothesis Tracking MHT	PT	5	2	n/a	n/a	4	1	3	4
Probabilistic Multiple Hypothesis Tracking PMHT	PT	5	2	3	3	3	1	3	n/a
Mean shift	KT	1	2	3	2	1	1	n/a	2
KLT tracker	KT	1	3	3	2	1	1		1
Simple Template matching	KT	1	1	1	2	1	2	1	1
SVM	KT	1	3	3	2	1	1	1	2
Layer/Layering based Tracking	KT	5	1	3	2	1	2	1	1
Eigentracking	KT	1	1	3	2	1	1	1	n/a
Shape Matching	ST	1	1	2	2	4	1	0	3
Contour Tracking	ST	5	1	3	2	4	1	1	3

D. Comparison

1) SilhouettComparison of tracking methodologies based on the three categories kernel, silhouette, and point: The spider Fig. 8 illustrates a comparison of silhouette, point, and kernel tracking category methodologies relied on the Number of objects tracked, Occlusion, illumination variation, speed, Scale variation, Enter field of view, Optimal, outliers.

2) Comparison of the three categories: According to Fig. 8 results, Multiple Hypothesis Tracking is the most favored algorithm within the three categories. Most of the advantages dealing with tracking multiple objects, handling occlusion, and give optimal solutions. Without ignoring that can handle object appearance and disappearance. There is a big lack of handling fast motion that should object-tracking methodologies take into consideration. Regarding our Comparison of Silhouette tracking, methodologies see Fig. 6, they are a bit similar to each other and that describes that they belong to the same category.

Fig. 5 shows that SVM within Kernel tracking methodologies is dealing better with occlusion and outliers. Regarding point tracking, in Fig. 7 multiple MHT and PMHT are gaining the best results due to their speed and their way to handle outliers, occlusion.

3) Comparison based on Table V: The Table V illustrates see that contour tracking, particle filter, MGE tracker, GOA tracker, JPDAF, MHT, and PMHT are gaining the best results to the other methods.

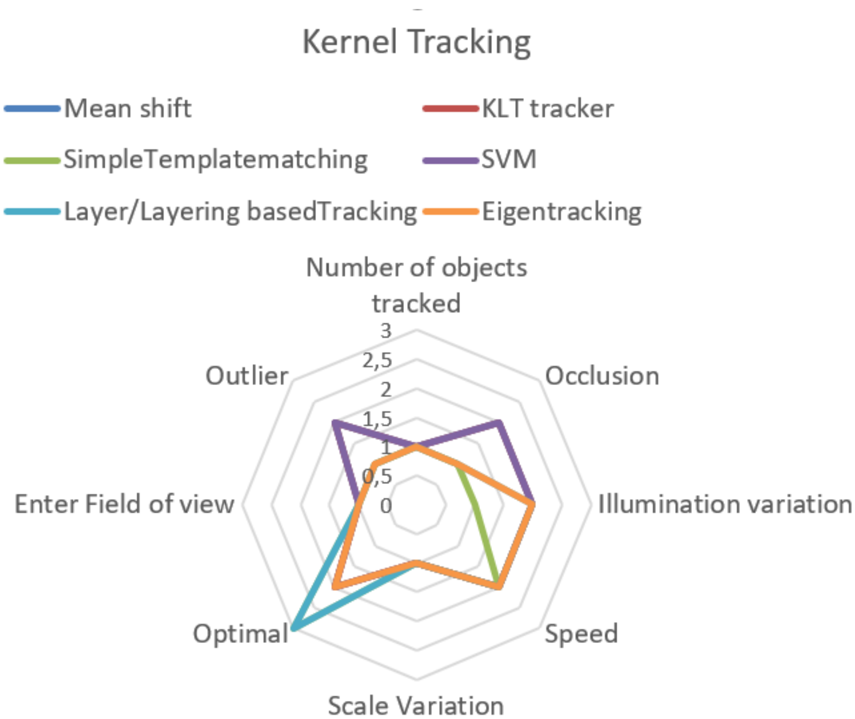

Fig. 5. Graph of Multicriteria Comparison of Kernel Tracking Methodologies.

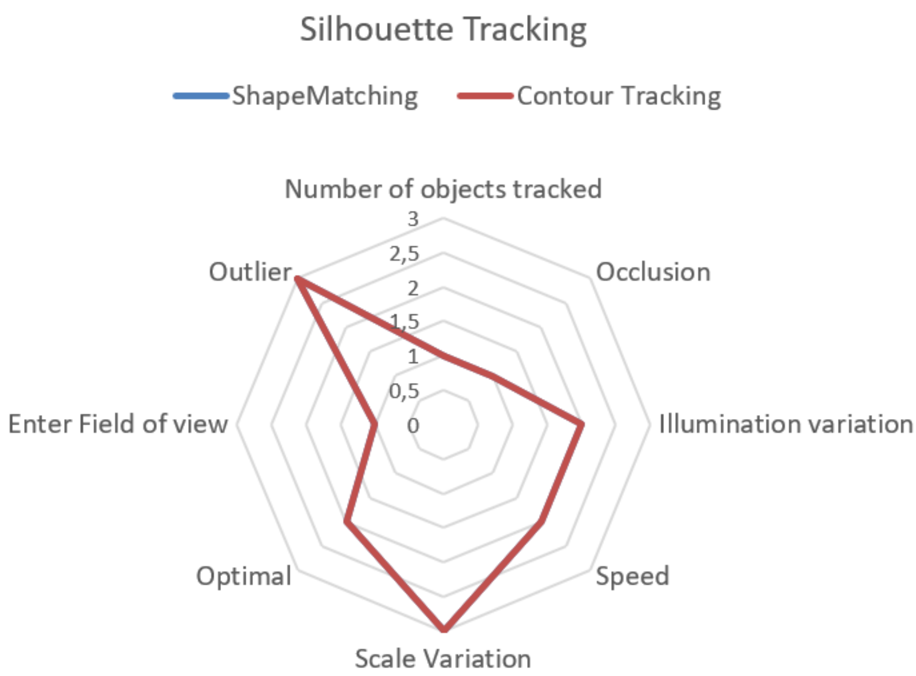

Fig. 6. Graph of Multicriteria Comparison of Silhouette Tracking Methodologies.

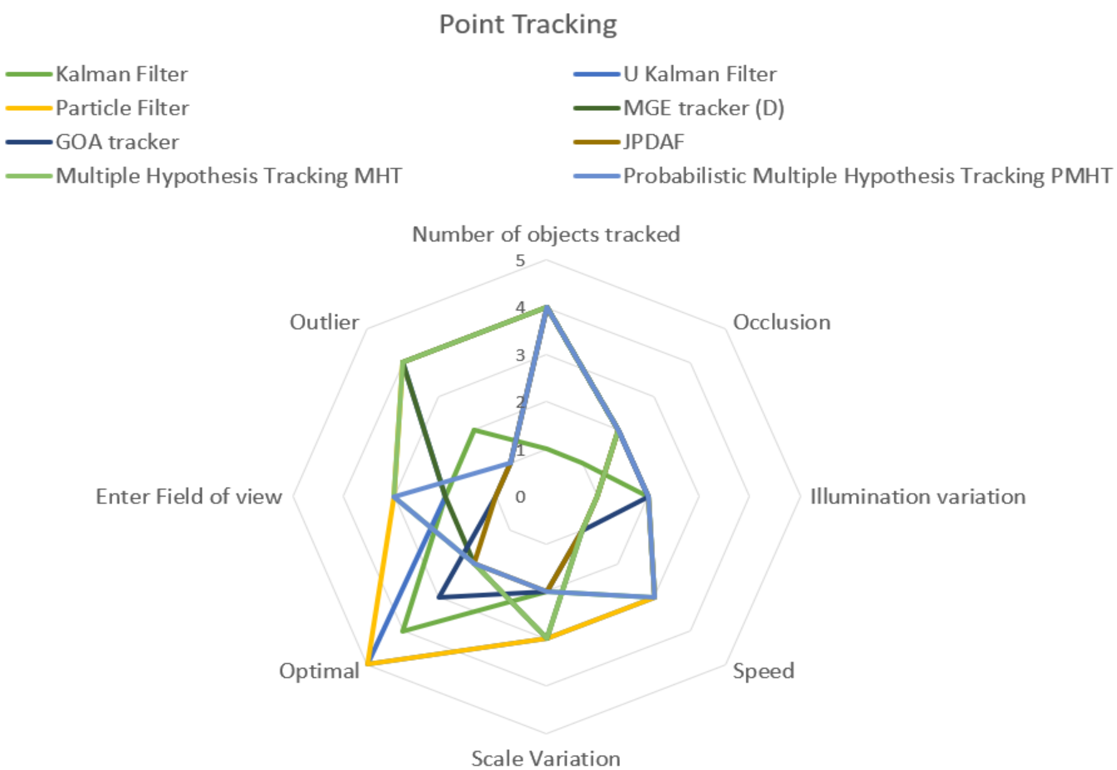

Fig. 7. Graph of Multicriteria Comparison of Point Tracking Methodologies.

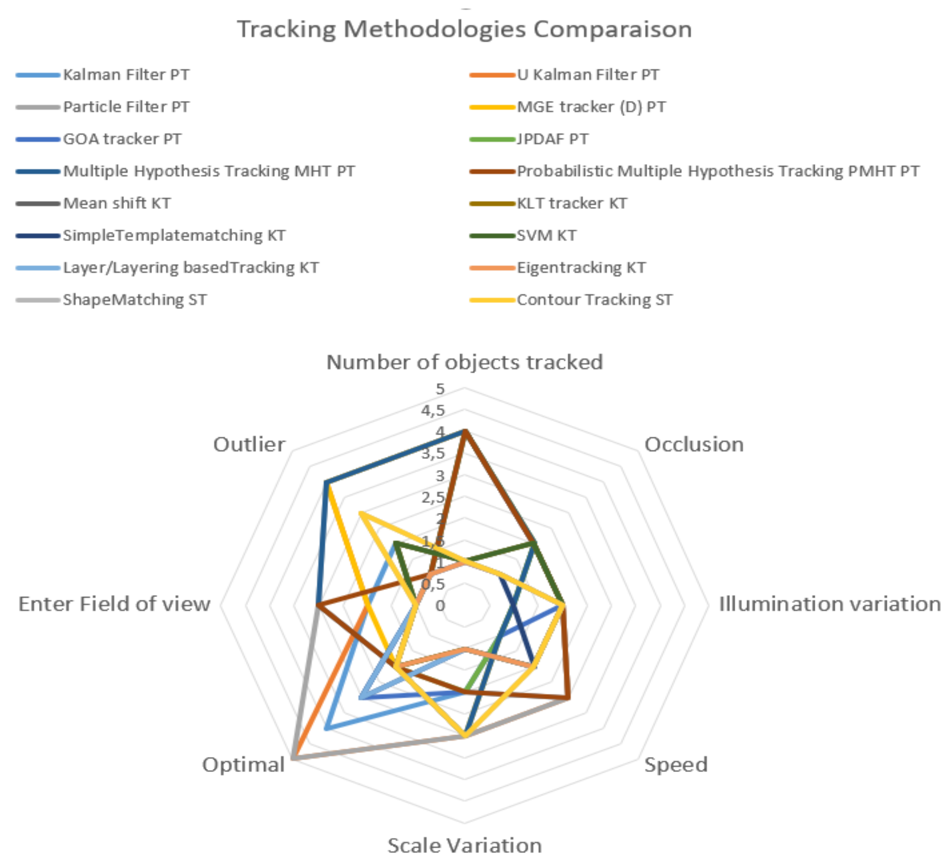

Fig. 8. Multicriteria Spider Graph.

TABLE V. COMPARING THREE OBJECT TRACKING CATEGORIES' METHODOLOGIES

Method	Score
Kalman Filter PT	2%
U Kalman Filter PT	10%
Particle Filter PT	10%
MGE tracker(D)	10%
GOA Tracker PT	10%
JPDAF	10%
MHT PT	10%
PMHT PT	10%
Mean shift KT	2%
KLT Tracker KT	2%
Simple Template Matching KT	2%
SVM KT	2%
Layer/ Layering based Tracking KT	10%
Eigen tracking KT	2%
Shape Matching ST	2%
Contour Matching ST	10%

VI. DISCUSSION

According to the previous results, some algorithms are dealing better with multiple objects such as Particle Filter, MGE tracker, GOA tracker, JPDAF, multiple hypothesis tracking, and so on. Point and Silhouette methodologies deal better with scale variation. However, they do not handle fully occlusion. Regarding kernel tracking methodologies they handle occlusion but they do not go forward with handling multiple objects.

On the one hand, relying on the comparative study-based WSM method Point Tracking is better to deal with small objects and tracking multiple objects, however, is not good to deal with occlusion and object appearance and disappearance.

On the other hand, Kernel tracking methodologies are handling better occlusion at the meanwhile estimate the object motion but they don't deal with multiple objects also this method is not a good choice to handle multiple objects.

Regarding Silhouette Tracking methodologies are dealing better with tracking object based on silhouette. This method is accurate to track objects or targets because of its ability to track different shapes. But these techniques are not good to handle occlusion at the same time these methods are not better to handle multiple objects.

Multiple object tracking is still facing a wide range of challenges. We could not find one category or method that deals with all of these challenges. Each algorithm or method is mastering to handle a challenge. Hope to find a hybrid method that deal with all these issues.

VII. CONCLUSION

A comparison of object tracking methods is has been presented in this research. This project has begun with the identification of a group of relevant works that are implementing these methods and the proposal of object tracking methods that fits the needs of various areas. Then a list of research areas that are concerned by these works has been discussed. There is also a set of criteria that this comparison has been based on. Using the Weight Score Model, the scores for each algorithm evaluated have been obtained. Various scores or results not only have been assisting us in determining an overall ranking amongst these platforms, but they have also revealed their internal strengths and shortcomings concerning each criterion.

This research has identified a collection of failures that object tracking algorithms face. The main problems that platforms face are the number of targets and it is optimal. Researcher must provide an algorithm that considers optimal aspects to provide an accurate model or algorithm of object tracking to the wide range of the research areas, such as surveillance, robotic, and other fields. The researchers must create a model or algorithm that could tackle and operate the different challenges, dealing with the different problems carefully due to the crucialness of this such as the biomedical one. Finally, researchers must embrace the resources used, which is a set of tools for increasing product quality and lowering development costs while also ensuring optimal delivery for users.

Future work will focus on the measurement of the accuracy of each method under each challenge. Our main goal is to implement, test, compare and analyze the results of point tracking methods, kernel tracking methods, silhouette tracking methods that we are going to implement to track multiple objects/ targets. Our main aim is that we are going to decorticate models or algorithms relying on their architecture, iteration, practical use, and their uniqueness. At the end, a summary table of the comparison is developed.

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Mobile Malware Classification for iOS Inspired by Phylogenetics

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***Abstract*—Cyber-attacks such as ransomware, data breaches, and phishing triggered by malware, especially for iOS (iPhone operating system) platforms, are increasing. Yet not much works on malware detection for the iOS platform have been done compared to the Android platform. Hence, this paper presents an iOS malware classification inspired by phylogenetics. It consists of mobile behaviour, exploits, and surveillance features. The new iOS classification helps to identify, detect, and predict any new malware variants. The experiment was conducted by using hybrid analysis, with twelve (12) malwares datasets from the Contagio Mobile website. As a result, twenty-nine (29) new classifications have been developed. One hundred (100) anonymous mobile applications (50 from the Apple Store and 50 from iOS Ninja) have been used for evaluation. Based on the evaluation conducted, 13% of the mobile applications matched with the developed classifications. In the future, this work can be used as guidance for other researchers with the same interest.**

Keywords*—*iOS; mobile malware; reverse engineering; exploitation; phylogenetic

I. Introduction

Currently, smartphones based on Android and iOS are commonly and widely used across the world. Yet, they also possess security concerns, especially security exploitation by malware such as ransomware and cryptojacking [1]. Unfortunately, the rapid increase of smartphone users contributed to mobile malware growth in the iOS environment. Malware is referred to as software that can infect devices, software, or networks with malicious attention without the owner's consent. It can harm the victim with malicious activities such as stealing confidential information, identity theft, and spying on the victim. There are different kinds of malware such as viruses, Trojan, spyware, worms, and ransomware. It will cause a lot of chaos when the malware has successfully penetrated the smartphone system.

Whenever new vulnerabilities are released, Apple will update or patch to fix the weaknesses. By keeping the patch up to date, Apple makes sure the devices are secure enough to use. The malware attacks are carried out by attacking the kernel, giving the attacker private APIs (Application Programming Interfaces) and permission, and eventually gaining confidential information about the user. Unfortunately, there is a growing number of malwares attacking iOS devices. For example, it uses private APIs to implement malicious intent and view and steal its data. Fig. 1 shows statistics on the detection of malware for iOS by Welivesecurity [2].

Compared with Android, iOS is considered more secure. For example, in the iOS platform, the hardware, software, and even their booting process are monitored and secured by Apple procedures [3]. This scenario has an impact where many attackers tend to focus on Android malware rather than on iOS. In addition, based on the Mc Afee Labs Threat report on June 2018 shows a drastic increase in malware growth, and there were almost 2.9 million samples recorded [4]. Furthermore, high-risk vulnerabilities were detected in 38 percent of iOS mobile apps in 2019 compared to 43 percent of Android mobile apps [5]. Indeed, 40 percent of iOS malware attacks in 2017 targeted banking services [6]. As in Q1 2020, new mobile malware cases have surged by 71 percent, and new iOS malware grew by over 50 percent [7]. Hence, this paper presents a new mobile malware classification for iOS inspired by phylogenetics to overcome the above challenges. Phylogenetics is a term borrowed from biology and has been mapped into the cybersecurity field. It can be used to detect and predict malicious activity. This approach consists of malware behaviour, vulnerability exploitation, and surveillance features [8].

The proposed malware classification developed in this paper can detect any malware attacks against possible social media and online banking exploitation. This new iOS classification aids in the detection, identification, and prediction of new malware variants.

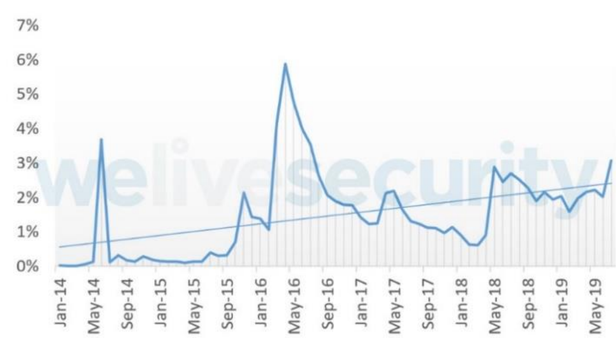

Fig. 1. Detection of Malware for iOS.

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This paper is organized as follows. Section II discusses the related works, while Section III presents the methods used, and Section IV explains the findings. Finally, Section V discusses the conclusions reached by this paper.

II. Related Work

A. iOS Malware Attacks

iOS malware attacks have been increased rapidly from years to years, and many researchers try to invade the issues and solve them to reduce the impact. Attackers evolve with the latest technology to ensure their intention to exploit user data can be conducted smoothly without interruption. Work by [9] found Trident worm and exploited three types of vulnerabilities once the link is clicked. Once it has been executed, the attackers will have the privilege to read, write, and any software in the infected device. Next, work by [10] found iKee Worm, which gathered logs on many jailbroken devices by scanning the OpenSSH port and used the root account and default password, and once infected, it will scan the surrounding IP address to spread the worm. They also found the YiSpecter worm, where the malware used ISP (Internet Service Provider) traffic, Window SNS (Self/Non-self) worm and offline applications installation, and other routes for transmission. It installed malware applications intending to collect private user information. Then, a previous study by [11] used Xcode Ghost worm where malware was sitting in the background of legitimate apps, then it did the data mining and injected malware in the apps when compiled. It possesses a new capability to prompt a fake alert dialogue to phish user credentials, hijack opening specifics URLs, and read and write data in the user clipboard. Work by [12] found AceDeciever that infects any Apple device connected to infected PC (personal computer) were capable of obtaining Apple ID (identification) and password. Finally, work by [13] found Keyraider worm, where it intercepted iTunes traffic and stole user login credentials, GUID (Globally Unique Identifier) devices Apple requests push service certificates and private keys, and iTunes receipts for purchase. It then sends this data to a remote server. Based on these previous studies, it can be concluded that there is a growing number of malwares attacking iOS users, and a solution to overcome these challenges is urgently needed. So, this paper proposes a new mobile malware classification as one of the mitigation solutions for the above challenges.

B. Phylogenetics

The phylogenetics aims to discover the origin of malware genes evolving [8]. It deals with evolutionary history and uses a tree diagram for different organisms and taxonomic groups. Malware phylogenetics emphasizes the similarities and relationships between a set of malwares. For example, a few types of phylogenetics tree models are the minimum spanning tree (MST), the persistent phylogeny tree, and the dendrogram [14]. Works by [15] used process mining which detects temporal logic properties designed to detect Android malware families and track the phylogenetic tree. [16] also used process mining where the program calls trace from a mobile application to classify associations and repeat execution patterns. Work by [17] used fuzzy clustering algorithm, where a malware program's syscalls can be modelled to produce a malware fingerprint with a number of associations and recurrent execution patterns. The author in [18] used discrete time Markov chain (DTMC) due to the paired KLD (Kullback-Leibler Divergence) and JSD (Jensen-Shannon Divergence) track calculation, it is computationally intensive. Bayesian network algorithm used by [19], learn a Directed Acyclic Graph (DAG) from observational data using statistical inference of conditional dependence and an informative antecedent to partial variable ordering. Work by [20] used extension of graphical lasso to discover a precision sparse matrix based on the kernel's combined matrix. An example of the phylogenetics diagram is depicted in Fig. 2. In this paper, there are three features mapped into phylogenetics to develop the classification. The identified features are malware behaviour, iOS version, and surveillance features.

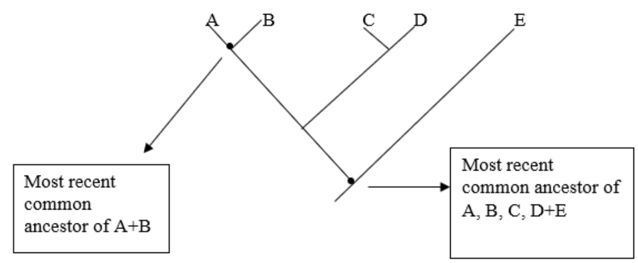

Fig. 2. Phylogenetic Diagram.

C. Features Mapped to Phylogenetic

Malware behaviour can be classified into five parts: infection, activation, payload, operating algorithm, and mitigation [8]. In dynamic analysis, these five components are significant to classify malware based on their behaviour. The malware behaviour used EDOWA (Efficient Detection of Worm Attack) worm classification as the underlying concept [21]. Apple keeps satisfying their customer by serving them with the best version of iOS. The version must be updated to make sure the user is secured enough from any current security issues. The update also has some new features that can help user’s life easier [22]. Surveillance features used in this research come from 5 basic functions in the smartphone, consisting of call, SMS (Short Message Service), photos, audio, and GPS (Global Positioning System). All these features are dangerous whenever been exploited. The attacker can profit by exploiting either one of its features [23].

As one of the mitigating options for the stated challenges above, this research presents a new mobile malware classification based on phylogenetics. Three features are mapped into phylogenetics, which are malware behaviour, iOS version, and surveillance features.

III. Methodology

The overall process involved in this experiment is summarized in Fig. 3.

The analysis took place once the malware had been executed. The findings were mapped during the research regarding malware behaviour, vulnerability exploitation, and mobile phone surveillance features to allow malware classification. Malware behavior is referred to as infection, payload, operating algorithm, activation, and propagation. Vulnerability exploitation refers to the iOS platform version, either iOS 10.x, 11.x, or 12.x, and the type of exploitation used. At the same time, mobile phone surveillance features are the features that attackers could use to exploit a mobile phone in the form of SMS,call log, camera, audio, and GPS. The mathematical formula for the proposed mobile malware classification is as follows:

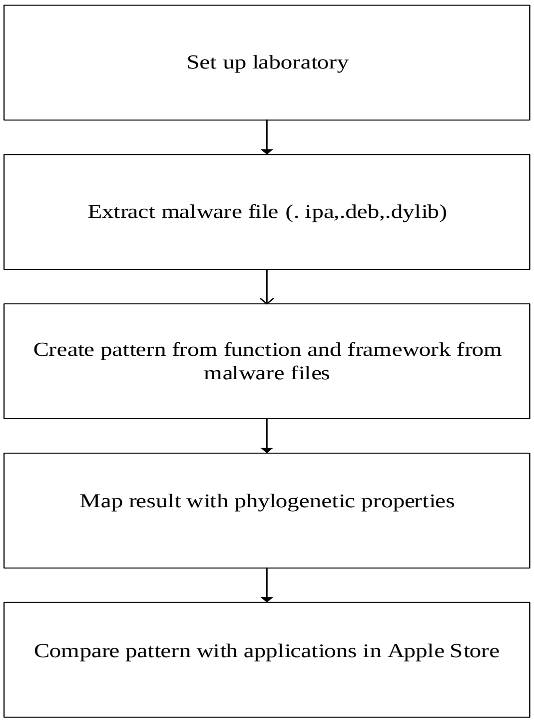

Fig. 3. Experimental Process.

Let α_1 be a malware architecture I, and $\alpha = \bigcap_{i=1}^{p} \alpha_i$, β_j be a mode attack j, and $\beta = \bigcup_{i=1}^{m} \beta_i$, γ_k be a connected asset in network k and $\gamma = \bigcap_{i=1}^{p} \gamma_i$.

Let M be the malware detection and T be a target asset. S is the detection model which can be defined in terms of the following function:

$$(M, T) = S \quad (1)$$

$$\text{where } M(\alpha, \beta, \delta) = \alpha + \beta + \delta \quad (2)$$

$$f(M_i, T_j) = S_{ij} \quad (3)$$

Where M represents the malware classification, T represents the target asset, and S is the detection model.

$$M(\alpha, \beta, \delta) = \alpha + \beta + \delta$$

$$\alpha = \alpha 1 \cap \alpha 2 \cap \alpha 3 \cap \alpha 4 \cap \alpha 5$$

$$\beta = \beta 1 \cup \beta 2 \cup \beta 3 \cup \beta 4 \cup \beta 5$$

$$\delta = \delta 1 \cup \delta 2 \cup \delta 3 \cup \delta 4 \cup \delta 5$$

$$\begin{array}{cccc} M_i & \alpha & \beta & \gamma \\ \vdots & & \ddots & \vdots \\ M_n & & \cdots & \delta_n \end{array}$$

where:

$\alpha 1 - \alpha 5$: payload, infection, operating algorithm, activation, and propagation

$\beta 1 - \beta 5$: iOS 10.x, iOS 11.x, iOS 12.x, iOS 13.x, iOS 1x.x

$\delta 1 - \delta 5$: SMS, call log, GPS, audio, and camera.

IV. Results

After the exploitation has been discovered, all the exploitation script's functions will be traced to their main frameworks to see what framework they are attacking during the malicious act. Then, the exploit is mapped into phylogenetics. The mapping result showed either the malware might lead to possible social media or online banking exploitation. If SMS or call is being exploited, it can be concluded as online banking exploitation. If any of those five features are being exploited, it is social media exploitation. Table I shows malware analysis results based on the mapping with the phylogenetics.

TABLE I. Malwares Mapped To Phylogenetic

Classification	**Description**	**Social Media Exploitation**	**Online Banking Exploitation**
E1: Unflod Malware			
α_1 - α_5 (Malware Behaviour)	**Payload:** Phishing. Stole the device's apple id, password and sent them in plaintext to the server. **Infection:** Host. From Chinese Cydia repositories **Operating Algorithm:** Stealth. **Activation:** Self-activation. Initiated their execution by exploring vulnerabilities in services that are available. **Propagation:** Passive monitoring. The malware infected those jailbroken devices that have download piracy Chinese repositories.	Possible exploitation	Possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1 (iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	GPS, SMS, call, audio, and photo		

E2: Spad Malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Destructive. Change the actual owner id for the ads into their id to obtain the revenue. **Infection:** Host. Result of some action taken by a user. The criminal hooks the legitimate functions and adds their tweaks. **Operating Algorithm:** Stealth. **Activation:** Human trigger. The malware will be functioning whenever the ads operate. **Propagation:** Passive monitoring. The malware only can infect jailbroken devices.	No possible exploitation	No possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	No surveillance features are involved as the attacker only exploits affect ads section		
E3+E4+E5+E6: Inception Malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Phishing. Collect device information and recording audio and send it to the c2(Command and Control) server. **Infection**: Host, Result of some action taken by a user. The malware will inject into the host whenever the user clicks a malicious link or download any doc files. **Operating Algorithm:** Stealth. **Activation:** Human activation. The malware will be executed when the file has been opened. **Propagation:** Passive monitoring. The malware only can infect those jailbroken devices that click the link or open the trojanized file.	Possible Exploitation	Possible Exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	GPS, SMS, Call Log, Audio, and Photos		
E7+E8: Xcodeghost Malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Destructive. Modifies Xcode, infects and steals some device information, and then sends it to the c2 server. **Infection:** Host. Infected the apps that Xcodeghost produced. **Operating Algorithm:** Stealth. **Activation:** Human trigger. The malware will be functioning whenever the apps been open. **Propagation:** Passive monitoring. The malware only can infect the user of the apps that have been created using Xcodeghost	No possible Exploitation	No possible Exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	No surveillance features are involved.		
E9+E10+E11+E12: Wirelurker Malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Phishing. Exfiltration of user data and exfiltration of application usage and device serial number information. **Infection:** Host. Infected through USB (Universal Serial Bus) when the device connects with the infected Mac. **Operating algorithm**: Stealth. **Activation:** Self-activation. It will start the malicious act once the malware has been injected into the device. **Propagation:** Passive monitoring. The malware only can infect users that connect their device with the infected Mac.	Possible exploitation	Possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	GPS, SMS, Photos, Audio, and Call All the surveillance features can be exploited by the attacker if they can brute force the victim's Apple ID as they already get the Apple ID.		
E13: Zerghelper malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Installing backdoor. Installed via a backdoor, requests the user to give Apple ID, shared Apple ID to other users, abuses the Apple ID by running different operations in the background, and abuses enterprise and personal certificates.	Possible exploitation	Possible exploitation

	Infection: Host. Spread via host file (mobile app). It camouflaged itself in a genuine mobile app. **Operating algorithm:** Stealth. **Activation:** Scheduled process. It is based on the location of the user and activates its payload only in China. **Propagation:** Passive monitoring. The malware camouflaged itself by claiming to resolve stability issues. It then guides the installation for two configurations. Only users in China will see the payload.		
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	SMS		
E14: Oneclickfraud malware			
α_1- α_5 (Malware Behaviour)	**Payload**: Destructive. Installing another app through OTA. **Infection:** Host. Distributed through an adult site. **Operating algorithm:** Stealth. **Activation:** Human trigger. The malware will be functioning whenever the play button been clicked. **Propagation**: Passive monitoring. The malware only can infect the visitor of the adult site	No possible exploitation	No possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below		
δ_1 - δ_5 (Surveillance Features)	No surveillance features involved		
E15: Xsser Malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Phishing. Act as spyware and harvesting information from user device thus send it to c2 server. **Infection:** Host. Installed via a rogue repository on Cydia, the most popular third-party application store for jailbroken iPhones. **Operating algorithm**: Terminate and resident. When triggered, xRAT will clean out its installation directory before issuing a package manager command to uninstall itself. Additionally, the developers behind xRAT created an alert system, flagging the malware operator if any of the following antivirus applications are present on a compromised device. **Activation:** Self-activation. It will start the malicious act once the malware has been injected into the device. **Propagation:** Passive monitoring. The malware only can infect users that use the repositories.	Possible exploitation	Possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	GPS, SMS, and Photo		
E16+E17: Muda malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Display advertisements over other apps or in the notification bar and ask users to download iOS apps it promoted. **Infection:** Host. Spreads via third-party Cydia sources in China and only affects jailbroken iOS devices. **Operating algorithm**: Stealth. **Activation:** Human trigger. The malware will be functioning whenever the apps are open. **Propagation:** Passive monitoring. The malware only can infect jailbroken devices that using third-party Cydia repositories.	No possible exploitation	No possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	No surveillance features are involved.		
E18+E19+E20: Tinyv malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Destructive. It connects with its C2 server to get remote commands and install specified IPA file or DEB file(s) in the background, uninstalling specified IPA app or DEB package(s) in the background and changing the /etc/hosts file. **Infection:** Hosts. Repackaged into some pirated iOS apps for jailbroken devices.	No possible exploitation	No possible exploitation

	Operating algorithm: Stealth. **Activation:** Human trigger. The malware will be executed whenever the apps are being used. **Propagation:** Passive monitoring. The malware only can infect the user that installed the pirated iOS apps.		
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below		
δ_1 - δ_5 (Surveillance Features)	No surveillance features involved		
E21+E22+E23+E24+E25+E26+E27: Yispecter Malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Destructive. Abusing enterprise certificates, installing malicious apps, uninstall apps, and self-monitoring and updating, collecting, and uploading device information, changing safari configurations, hijacking other apps execution, and pretending to be system apps. **Infection:** Host. Through hijacking of traffic from nationwide ISPs, an SNS worm on Windows, and an offline app installation and community promotion. **Operating algorithm:** Stealth. **Activation:** Self-activation. It will start the malicious act once the malware has infected the device. **Propagation:** Passive monitoring. The malware only can infect users that use the repositories.	No possible exploitation	No possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	No surveillance features are involved.		
E28+E29: Keyraider malware			
α_1- α_5 (Malware Behaviour)	**Payload:** Destructive. It is stealing Apple account data, certificates, and private keys. **Infection:** Host. Distributed through third-party Cydia repositories in China. **Operating algorithm:** Stealth. **Activation:** Human trigger. The malware will be functioning whenever the apps are open. **Propagation:** Passive monitoring. The malware only can infect jailbroken devices that using third-party Cydia repositories.	Possible exploitation	Possible exploitation
β_1 - β_5 (iOS Chain)	iOS version: Chain 1(iOS 10.x and below)		
δ_1 - δ_5 (Surveillance Features)	GPS, SMS, Call Log, Audio, and Photos		

Table I shows 13 of the 29 malware classifications mapped to phylogenetics, which can be used against possible exploitation for social media and online banking. The identified classification are E1 (Unflod malware), E3+E4+E5+E6 (Inception malware), E9+E10+E11+E12 (Wirelurker malware), E13 (Zerghelper malware), E15 (Xsser malware and E28+E29 (Keyraider malware).

In summary, the malwares have been reported based on the classification proposed. The analysis fits with the elements required for the classification based on this classification. Furthermore, every malware examined contains components that can be used for further exploitation.

Next, for the evaluation process, 50 anonymous apps from Apple Store and another 50 from the third-party store were selected. This is to test the practicality of the proposed classification in detecting any possible exploitation in the tested apps. As a result, 13% of the tested apps were identified with possible security exploitation. Two apps were from Apple Store, and 11 apps were from iOS Ninja. This 13% represents the possible exploitation either against social media or online banking.

V. Conclusion

Based on these experimental results, the proposed malware classification developed in this paper can be used to detect any malware attacks against possible exploitation for social media and online banking. These new iOS classification helps to identify, detect, and predict any new malware variants. Another important consideration for future improvement would be to revise the frameworks and functions involved in the iOS architecture from time to time and integrate with artificial intelligence-based alarms. Malicious apps will use the combinations of frameworks and functions in the iOS architecture to exploit the targeted feature successfully. Furthermore, as a newer iOS version will be introduced, a new framework and functions may also be offered. Hence, there is a need to add more malware classifications based on the mobile malware classification formulation developed in this paper.

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ANNMDD: Strength of Artificial Neural Network Types for Medical Diagnosis Domain

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***Abstract*—The abundance of medical evidence in health institutions necessitates the creation of effective data collection methods for extracting valuable information. For several years, scholars focused on the use of computational techniques and data processing techniques in order to enhance the study of broad historical datasets. There is a deficiency to investigate the collected data of health disease in the data sources such as COVID-19, Chronic Kidney, Epileptic Seizure, Parkinson, Hard diseases, Hepatitis, Breast Cancer and Diabetes, where millions of people are killed in the world by these diseases. This research aims to investigate the neural network algorithms for different types of medical diseases in order to select the best type of neural network suitable for each disease. The data mining process has been applied to investigate the mentioned medical disease datasets. The related works and literature review of machine learning in the medical domain were studied in the initial stage of this research. Then, the experiments behind the initial stage have been designed with six neural network algorithm styles which are Multiple, Radial Based Function Network (RBFN), Dynamic, Quick and Prune algorithms. The extracted results for each algorithm have been analyzed and compared with each other to select the perfect neural network algorithm for each disease. T-test statistical significance test has been applied as one of the investigation strategies for the NN optimal selection. Our findings highlighted the strong side of the Multiple NN algorithm in terms of training and testing phases in the medical domain.**

Keywords—Medical data; neural network algorithm; multiple; radial based function network; dynamic; quick; prune; accuracy

I. Introduction

Currently the number of records in health databases is so huge thanks to technology which has made it possible to securely and effectively store and retrieve this large volume of data. The process of creating meaningful patterns or evidence from medical data sites is medical diagnosis [1]. The extract from these medical datasets helps the physician to diagnose disease in the early stages. The problem is largely solved by having adequate tools for dealing with such large data. A huge amount of research in this area has been carried out and it is still a very interesting area. There are numerous classification algorithms available, and it is worthwhile to do a more in-depth examination of these algorithms and their success on medical datasets such as [1-7]. We perform studies in this paper on a number of medical datasets using a variety of familiar prediction algorithms. The objective is to evaluate if preprocessing techniques prior to classification can improve classification performance. Materials containing the missing values, contours and noise are well known, and few papers analyze the effect of pre-processing to the best knowledge of the author [3].

For future documentation and for preparing future procedures, most healthcare organizations and research institutes digitally store patient records. Because of the difficulty and size of information, the noise and lacking of values, mining is a tedious task and it is very difficult to analyze in this heterogeneous medical dataset [8]. Most healthcare organizations and medical research institutions store their patients' data digitally for future references and future treatment planning [8]. Healthcare is a field which is closely linked to the daily life of all owing to the high uncertainty [9]. Machine learning (ML) is a powerful and flexible tool for analyzing and predicting biological outcomes and clinical data[10]. Early diagnoses benefit from the detection of useful trends in the medical dataset[11].

Machine Learning (ML) and Artificial intelligence (AI) and master learning are key terms for a range of algorithms, allowing computers to detect and determine data patterns. Despite a quiet time, AI's abilities are an omnipresent part of mainstream culture in a number of activities, from automated digital assistants to self-driving vehicles. Given some positive advances in cardiovascular oncology, however, a major AI revolution has not yet occurred. Cardiovascular routine patient care accumulates large quantities of electronic health record (EHR) data. Integrating a large amount of diverse data in a busy clinical environment is a challenge, leading to marked underuse of data that could influence clinical decisions. Artificial intelligence (AI) applies in general to computational algorithms, such that machines can gain secret information without being programmed directly[12]. Machine learning techniques are attracting substantial interest from medical researchers and clinicians [13]. Data mining is the discovery process of patterns and trends from the enormous amount of data and examines the various existing data mining techniques [14]. Several studies helped to find the most appropriate neural network algorithms for the classification of medical data and also showed the value of pre-processing in improving classification performance. Therefore, this study has investigated the effectiveness and efficiency of the neural network algorithms (NN) in healthcare in order to select the significant NN method that helps the medical doctor to make a diagnosis decision for a specific disease. Most healthcare organizations and medical research institutions store their patients' data digitally for future references and future treatment planning [8]. In addition to being used by clinicians, decision support systems are also helpful in making medical decisions; they're built on two main types, and the better ones assist with precise, consistent and prompt responses [15].

As machine training (ML) is commonly accepted as a technique to choose from in the common diseases pattern classification and predictive modelling, due to its specific advantages in critical features detecting in some diseases, the problems of this study can be summarized as:

1) Need for a clear method to identify the disease into disease stages, pattern or status. The number of patients who are infected is growing in specific disease.

2) The urgent need for an intelligent system that helps in the process of diagnosing diseases for themselves.

The goal of this research is to see the most useful disease features in predicting status and general patterns which can help us select models and select hyper parameters. The goal of this study is to identify the efficiency and effectiveness of some machine learning algorithms such as Neural Network algorithms in the healthcare domain. Our main objective is to investigate the neural network algorithms to adapt to a function that can predict the discreet new input class [16]. In particular, this study investigates and reviews the current healthcare systems in order to detect the shortcomings that need to be improved. The significant role in this study is to find and predict an early disease stage that can save patients' lives using neural network classification methods in order to help medical doctors to take suitable diagnosis decisions. Diagnosis at an early stage, when it isn't too large and hasn't spread, makes successful treatment more likely.

This study comprises six sections. The introduction to this study is explained in Section 1. The Section 2 discusses related works. The upgraded methodology and its fundamental method are discussed in Section 3. Section 4 will discuss data classification using neural networks. Section 5 will illustrate the experiments and results of the investigation. Finally, Section 6 will summarize the study's findings.

II. Related Work

For future documentation and for preparing future procedures, most healthcare organisations and research institutes digitally store patient records. Due to the complexity and volume of data and the noise and lack of values and noise, this mining is a tedious task, making it very difficult to analyse this heterogeneous medical dataset [8]. Most healthcare organisations and medical research institutions store their patients' data digitally for future reference and future treatment planning [8]. Healthcare is a field which is closely linked to the daily life of all owing to the high uncertainty [9]. Machine learning (ML) is a powerful and flexible tool for analysing and predicting biological outcomes and clinical data [10]. Early diagnoses benefit from the detection of useful trends in the medical dataset [11]. It's almost old news by now: big data is going to transform medicine. However, it is essential to remember that the data is useless by itself. Data must be analysed, interpreted and acted upon to be useful. Thus, it is algorithms that will prove transformative, not datasets. Obermeyer. and Emanuel (2016) therefore believed that attention needs to be shifted to new statistical tools in the field of machine learning, which are critical for everyone in the 21st century who practises medicine [17]. Shameer, et al. discussed existing approaches that use machine learning and bioinformatics for behavioural analysis as well as well as clinical, genetic and climatic methodologies in their talks [18]. Artificial intelligence (AI) applies in general to computational algorithms, such that machines can gain secret information without being programmed directly [12]. The computational study of machine learning is drawing significant attention from academics and clinicians alike [13]. The best of these schemes assist doctors in making decisions while others play a crucial part in making them [15]. Machine learning is the discovery procedure of patterns and trends from the enormous amount of data This study examined the various existing data mining techniques [14]. This study helps to find the most appropriate neural network algorithms for the classification of medicinal data and also will show the value of pre-processing in enhancing prediction results.

Much of the computer-based rule sets that deal with healthcare situations are "expert systems". Computer simulations operate in the same manner as ideal medical students: they apply theories to new cases. In the other words, machine learning methods go through training programs. The algorithms start with the patient stage, working their way through large quantities of variables in the process of compiling information before they come to a conclusion that can be applied to a variety of different patients.

Standard regression models, such as the result, the covariates, and statistical functions, may be seen to be in one way an extension of this phase Nonlinear, and immersive forms will work with a large number of predictors. When statistics are not feasible, the integration and interpretation of nuanced biomedical and healthcare data using artificial intelligence (CITL), supervised machine learning, deep learning, and cognitive approaches may be employed. H. Shameer, et al. (2018) was one of the research groups that explored the fundamentals and the uses of master learning algorithms; and they investigated the possible shortcomings and obstacles that machine learning could present in cardiovascular care[12]. Computer-based artificial intelligence and artificial-learning algorithms, respectively, are not all that novel in the medical field. In medical practice, risks are typically found in databases and are used to stratify patients or to provide anticoagulation guidance on which drugs to use [19]. This process entails analysing medical datasets in order to uncover intriguing trends in decision-making [14]. Machine learning algorithms have the potential to significantly increase the quality of healthcare in a variety of ways. Prognosis modelling algorithms assist health authorities in allocating money efficiently and physicians in selecting the right care choices for patients [19]. The multilayer perceptron of neural networks (MLPNN), logistic regression (LR) and validation is applied to test the predictive models [20].

Evaluation of machine learning algorithms depends on their accuracy, specificity and error rate [8]. Some used well-known regression equations, such as the simple linear and logistic, widely seen in clinical and modern statistical models such as Bayesian analysis, such as the data [18]. Analytic forecasting techniques include decision trees (J48) and

Bayesian analyses. The three mass classification methods used machine learning approaches to build three statistical models for the diagnosis of breast cancer. A standardised General Linear Model (GLM), a standard Support Vector Machine (SVM) with radial basis function, and single-layer neural networks were included. Predictive models were trained on the sample prior to the validation dataset. They used the validation datasets to compute the precision, sensitivity, and specificity of the three models – a decision aid for detecting breast cancer based on three kinds of decision tree factors. Simple decision tree (SDT) and Boosted simple decision tree (BDT). Many analyses were performed on several major classifiers including C4.5 (J48), Naïve Bayes, SMO, and Random Forests and compared with the results of these [11]. The Decision Tree C4.5 is unpruned. C4.5 is an increase in the previous ID3 algorithm of Quinlan. J48 creates decision trees using the idea of information entropy from the collection of labelled training data. J48 explores the uniform data benefit that results in choosing a data splitting attribute. The highest information gain attribute is used to make the decision. Then the little subsets use the algorithm. If all occurrences in a subset have the same class, the dividing strategy stops. A leaf node for this class is then made in the decision tree. The algorithm of Naive Bayes depends on conditions. It is using Bayes Theorem, an equation which calculates a probability by inspecting the recurrence of historical data values and values mixes. Given the probability of another opportunity that already occurred, Bayes' theorem finds the possibility of an occasion [21]. The document 'Prediction of diabetes use of the Bayesian Networks,' suggested by Mukesh Kumari et al. [22]. This article proposed to predict people, whether diabetic, not diabetic or pre-diabetic, by classifying the Bayesian Network. The dataset used is collected from a hospital that collects information from people with and without diabetes. Weka is the tool used for the study and exam. On the dataset of persons collected from the hospital, classification algorithm is applied and the results have been obtained. The author analysed the attributes' values to determine whether a certain individual is diabetic, non-diabetic or pre-diabetic in a dataset. The fact that a man is diabetic, non-diabetic or pre-dentinal had led to the determination of attributes such as qfast Gtt, casual Gott and diastolic blood pressure values above a given amount. The author concluded that 99.51 was best accurate in the classification with the Bayesian system. The paper 'Improved J48 Classification Algorithm for Diabetes Prediction' was proposed by Gaganjot Kaur et al. [23]. This work manages successful data mining to predict diabetes in patients' medical records. Today, diabetes in all populations and all ages is an extremely regular infection increasing the risk of developing renal disease, nervous damage, damage to the venous tract and visual impairment is a result of coronary disease. This paper uses the Pima Indians Diabetes Data Set which collects data from and without diabetes patients. Using the modified J48 classifier, the data mining method accuracy rate is determined. The WEKA data mining tool was used for manufacturing the J48 graders as a MATLAB API. The results of the test showed that the calculation J-48 is considerably different. Precision up to 99.87 percent have been demonstrated in the proposed calculation. V. Karthikeyan et al. [24]. Suggested the paper titled 'Data Mining Algorithm in Diabetes Disease Prediction Comparative Mining Classification (CDMCA)'. The data mining is an iterative development that is defined by discovery, by normal or manual techniques. Two types of supervised and uncontrolled classifications are classed in this paper, which uses the CDMCA data mining concept. This is the classification of the supervised diabetes-based data mining algorithms. It contains at least the plasma glucose diseases. This research describes C4.5, SVM, KNN, PNN, BLR, MLR, CRT, CS-CRT, PLS-DA as well as PLSLDA algorithmic discussion. The paper compares computer time performance, accuracy and data evaluated by means of a 10-fold Cross Validation error rate, and focuses on True Positive, True Negative, False Positive and False Negative and Accuracy. This shows that CS-CRT is the best algorithm. For this experiment, different data mining techniques are applied with the Pima Indian Diabetes Dataset. Pre-processing techniques convert raw data into useful and understandable formats to enable more precise results during algorithm execution. The features are extracted using permutation techniques from the pre-processed data and the classification techniques are performed in different combinations of features. The results achieved are evaluated for every combination [11].

Automatic risk prediction algorithms to guide clinical treatment; using unsupervised training techniques to more accurately phenotype complex conditions; and implementing algorithms to enhance the education of providers of healthcare intelligently [12]. Efficient classification of the medical dataset is then and now a big problem in data mining. Diagnosis, disease prediction and outcome accuracy can be enhanced if the relationships and trends are effectively extracted from these complex medical datasets [8]. The most serious scourge affecting the industrialised nations is CVD disease. Not only does CVD affect a large proportion of the population without warning but it also causes chronic suffering and disability in an even greater number [25]. The objective of this research was to collect the breast cancer data set for medical decision-making using clustering and data mining techniques [14]. Francis, F. and J. Saleema (2017) sought optimal features by combining the permutation input data attributes to improve the accuracy of the classifier [11]. These algorithms' performance assessments are based on precision, sensitivity, specificity and error rate. Heart statistics are the medical information used in this study[8]. BNs have been effective in developing powerful algorithms which can manage very large datasets and create predictive models of high quality from medical data and genomic [18]. A directed acyclic graph is a graph in which each node represents a variable and each arc represents a connection. Each arc is interpreted by BNs as a direct impact on a child node (variable) by a parent node (variable) [18]. The SVM, MLPANN, and LR models had accuracy, area under the curve (AUC), sensitivity, and specificity of 90.4 percent, 86.5 percent, 98.2 percent, and 49.6 percent, 85.9 percent, 76.9 percent, 97.3 percent, and 26.1 percent, and 84.7 percent, 77.4 percent, 97.5 percent, and 17.4 percent, respectively. Meanwhile, the independent predictors were discharge time creatinine, recipient age, donor age, donor blood type, etiology of ESRD, and post-transplant recipient hypertension [20]. The trained algorithms were capable of classifying cell nuclei with a high degree of accuracy (0.94 – 0.96), sensitivity (0.97 –

0.99), and specificity (0.97 – 0.99). (0.85 – 0.94). The SVM method produced the highest accuracy (0.96) and area under the curve (0.97) values. When algorithms were organised in a voting ensemble, prediction performance improved somewhat (accuracy=0.97, sensitivity=0.99, specificity=0.95) [13]. The results indicated that SDT and BDT obtained overall accuracies of 97.07 percent with 429 accurate classifications and 98.83 percent with 437 right classifications, respectively, during the training phase. BDT outperformed SDT on all performance indicators. The receiver operating characteristic (ROC) and Matthews correlation coefficient (MCC) values for BDT in the training phase were 0.99971 and 0.9746, respectively, which were superior to those of the SDT classifier. During the validation phase, DTF attained a classification accuracy of 97.51 percent, outperforming SDT (95.75 percent) and BDT (97.07 percent) classifiers. For DTF, the ROC and MCC values were 0.99382 and 0.9462, respectively [15]. That is the promise of medical machine learning: the wisdom contained in decisions made by almost all clinicians and the results of billions of patients should inform each patient's care. That is, every diagnosis, management decision and therapy should be customised based on all known patient information [26]. With machine learning located at the peak of inflated expectations, they considered soften as subsequent crash into a "trough of disillusionment" by encouraging a greater appreciation of the capabilities and limitations of the technology before they counter an idealised and unrealisable standard of perfection with computerised systems (or humans) [19]. Firstly, machine learning can improve the prognosis dramatically. Second, much of the work of radiologists and anatomical pathologists would be replaced by machine learning. These doctors mainly focus on the interpretation of digitised images. Firstly, machine learning can improve the prognosis dramatically. Second, much of the work of radiologists and anatomical pathologists would be replaced by machine learning. These doctors mainly focus on the interpretation of digitised images [17]. This would reduce the burden on doctors, increase and speed up access to care, reduce resources and cut costs for patients [10].

In the 18th century [27] Sir Galton introduced the first linear regression. Linear regression is a statistical method for modelling the connection between a variable dependent and one or more explicative variables. It assumes that weighted amounts of input variables can be predicted. Normally this is the very first model you would analyse when the outcome variable remains constant before moving into more complex models. Reed et al. [28] said that the association between highly accessible electronic health records (EHR) and ED visits, hospitalisations and office visits for diabetes mellitus patients has been researched. They used a linear regression model with patient-level effects and found that the use of EHR was associated with a small decline in ED and hospitalisation, but not with office visit rate among patients with diabetes. Yaffe et al. [29] have taken an account of the non-independence of the proportions as time series in the annual controls from the Kaiser Permanente Northern California hypertension registry, configuring a log linear proportion regression on time to make auto-correlated errors possible. They found that the application of a large-scale hypertension program was associated with a major increase in hypertension control in comparison with national and state control rates among adults with hypertension. In patients treated with target agents, Yuasa et al. [30] investigated the correlations between original tumour size and the tamper reduction rate. They used linear regression analyses both univariable and multivariate to determine that only the initial tumour size was associated with the rate of tumour reduction. This could be beneficial for doctors who treat patients' metastatic renal cell carcinoma.

In certain ways the logistic regression is similar to the linear regression. Regression of logistics assumes that the result can be explained by a weighted amount undergoing a specific mathematical transformation named log it. This transformation allows for the mapping of all weighted sums into a value between 0 and 1, which can be interpreted as a chance of a binary result. Therefore, logistic regression is widely used in the result variable with two outcomes, for example, whether or not you have a disease. From Vries et al. [31] the relation between mortality and iatrogenic diseases occurring outside the operating room has been investigated. The investigators carried out a multidisciplinary safety examination list with the medication, surgical side and medication checked by six hospitals. The relationship between checklist and mortality was evaluated by logistic regression. The research demonstrated a link between the full checklist and a decrease in surgical complication and mortality and high-grade hospitals. The relationship between maternal risk factors and congenital urinary tract anomalies was examined by Shmorhavorian et al. [32]. The study was carried out in case-control. In cases in which children were diagnosed with urinary anomalies while controls did not display urinary tract anomalies, they received Washington state birth-hospital discharge records from 1987-2007. The analysis identified increased risk of renal anomalies for gestational diabetes, pre-existing diabetes, and maternal renal disease. The results of these incidents have been studied by Peterson et al. The most common medical conditions were described and the form of assistance given on board. Through means of logistic regression, they established syncopes, respiratory symptoms and gastrointestinal symptoms in most medical emergencies in flight. In 1996, Somogyi and Sniegoski [33] first launched Boolean networks. Boolean networks were easily deployed as genetic networks with their convenient representation. But because Boolean networks do not specifically demonstrate the uncertainty the data may have, the vague characteristic of a bio-system cannot be modelled. Also note that no arrows are used when a Boolean network is created; thus, no path or cause of the model is clear.

In mathematics, differential equations have a long history of modelling a biological system [34, 35]. Chen et al. have modelled a simplified dynamic gene control system (with transcription feedback). Differential equations are more likely to model biological processes than boolean networks, but the computing costs of using differential equations are high and many of the parameters are often not available to use differential equation models. Since most of the genetic trajectory dynamics seem to be non-linear, a linear model appears to be working only on the limited genetic trajectories.

The BN model has been used extensively to learn data predictive models. BNs can model causality on the basis of the knowledge, data or both of the researcher. It is also utilised in a large number of medical fields as it can easily infer[36, 37]. One practical limitation of BNs is the fact that inferences in BNs are virtually impossible with a large number (> 50) of modelled variables [37], a frequently used limitation of many reasoning methodologies. A causal BN (or short causal network) is a BN, in which the parent variable and each arrow are interpreted as direct causal influence and the variable explicitly connected to which the variable is called the child variable [38]. Fig. 1 displays the structures of the five variables describing genes of a hypothetical causal BN system. The structure of the causal network in figure. For example, 1 indicates that Gene1 may regulate the level of expression (a cause of influence) of Gene3 which in turn may regulate the level of expression of Gene5. A variable is independent from its non-descendant since its parents occur (i.e., direct causes). It gives rise to conditional independence relationships defined in a causal BN.

III. Suggested Model

This section discusses the methodology that was used for the medical data classification and diagnosis. It was necessary to develop a sound methodology prior to the implementation of this research in order to improve classification of medical data. Research design of this study is a combination of several stages, each stage contains a number of steps. First access to the datasets of people infected with disease form data repertory such as UCI. Then, we define the second phase for six sub-stages of Knowledge data mining discovery (KDD) process, including data selection, data preprocessing and cleaning, data transformation, data mining, evaluation, and interpretation. In the third phase we design the experiments of this study using neural network algorithms. The fourth stage discusses the results and discussion phase. The fifth stage research is results analysis.

Operational guidance framework provides a structured manner and is used to help the researcher to achieve their goals. It is important that the operational framework is organization of a systematic process in this study. The framework has been divided into two phases: operational framework of the main action named planning phase, and the implementation phase. In this study, each of these stages is made up of different stages, starting with a review of the literature in the planning stage and the end of the written report. Fig. 1 below shows the operational framework.

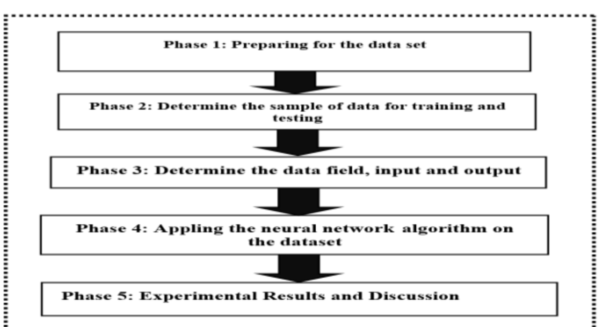

Fig. 1. Suggested Framework.

IV. Medicine Domain Classification using Neural Network

Artificial neural network (ANN) is a paradigm in the treatment of information based on biological nervous system data, such as the brain. The modern framework of the information management system is the core aspect of this model. It consists of many highly interconnected processing elements (neurons) which work together to solve specific issues. ANNs learn from examples, like people. For a specific application an ANN is configured by means of a learning process, like model recognition or data classification, Biology Systems Learning [39]. The goal is to create models of biological neural systems so that biological systems can understand how they work. Neuroscientists strive to link biological processing observed (data), neural theory (theory of statistical learning and theory of information) and biologically plausible neural methods for processing and learning (biological neuron network models) [40].

Neural networks are distinct from those of traditional computers in problem solving. Conventional computers use an algorithmic approach. In order to solve a problem, the machine follows a series of instructions. The computer can't solve the problem unless the specific steps the computer must take are known. This restricts conventional computers' problem solving capability to problems which we understand and are already able to resolve. But if computers could do things we do not know exactly how to do they would be much more useful [41].

ANNs are currently a hot area of medical research, and in the next few years they are expected to be widely used in biomedical systems. The research is currently primarily focused on modelling the human body parts and the recognition of diseases from various scans (for example, cardiograms, CAT scans, ultrasound scans).

Neural networks are suitable for identifying diseases using scans since a complex algorithm on how to recognise the disease does not need to be given. Neural networks learn by example to escape the need to classify the disease. A number of examples are needed which are representative of all the disease variations. The number of examples does not matter as much as the amount. The examples must be carefully selected for reliable and efficient performance of the system [42].

We provide some descriptions of the neural network types:

1) Quick: This approach chooses a topology using rules of thumb and features of the data the default number of hidden layers has changed in previous versions of clementine. The new process normally yields thinner layers that are quicker and more adaptable. if you get bad results at the default size, consider increasing the size of the "hidden" layer on the expert page. Fig. 2 shows the quick neural network structure.

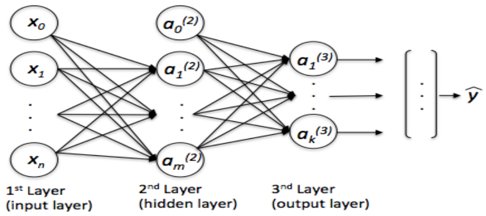

Fig. 2. Quick Neural Network.

2) Dynamic: It provides an initial topology, but adjusts it when training is underway. Fig. 3 shows the dynamic neural network structure.

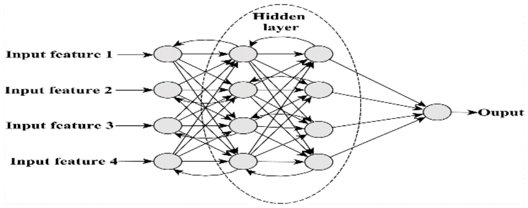

Fig. 3. Dynamic Neural Network.

3) Multiple: Several topologies are made (the exact number depends on the training data): pseudo-parallelization. The model with the lowest root mean square-squared error is declared the winner. Fig. 4 shows the multiple neural network structure.

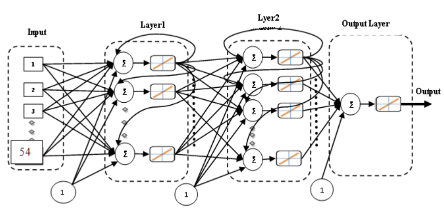

Fig. 4. Multiple Neural Network.

4) Radial based Function Network (RBFN): Similar to k-means clustering, the radial basis algorithm partitions the data on values for the target area. Fig. 5 shows the rbfn neural network structure.

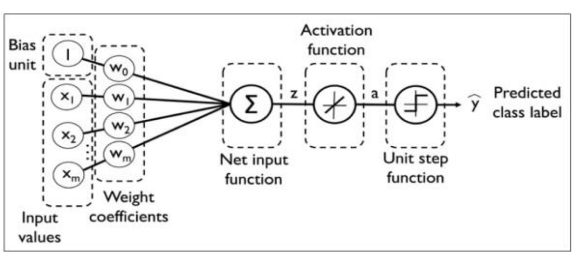

Fig. 5. RBF Neural Network.

5) Prune: Pruning is a compression technique that entails extracting weights from a learned model. Pruning is the process of removing unneeded branches or stems from a plant in agriculture. Pruning is the process of deleting superfluous neurons or weights in machine learning. Fig. 6 shows the prune neural network structure.

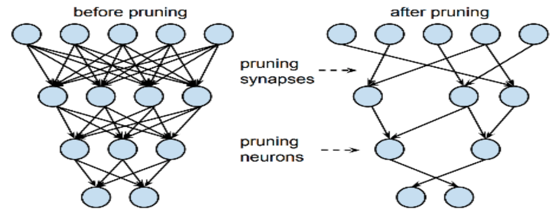

Fig. 6. Prune Neural Network.

The NN layout is motivated by the need to execute precise addition on a multidimensional array of information [43]. It can be thought of as a type of practical link network [37]. It employs a system design similar to that of classical regularization [44], in which the premise capacities correspond to the Green's components of the Gram's administrator associated with the stabilizer. The NN organization is obtained on the off-chance that the stabilizer exhibits outspread symmetry. From the estimation hypothesis's perspective, the regularization organization has three appealing properties [44, 45]: it can approximate any multivariate consistent capacity on a smaller space to a subjective degree of precision, given an adequate number of units; it has the best estimation property because the obscure coefficients are straight; and the arrangement is ideal by limiting a practical containment.

As illustrated in Fig. 7, the general function is a three-layer (J1-J2-J3) feed forward neural network. Each node in the hidden layer is activated by an activation function such as (RBF), denoted by (r). The hidden layer performs a nonlinear transformation on the input, whereas the output layer is a linear integrator that maps the nonlinearity to a new space. In general, the activation function is applied to all nodes; that is, NN nodes have the nonlinearity $(\vec{x})=\phi(\vec{x}-\vec{c}i)$, $i=1,\ldots,J2$, where ci is the prototype or centre of the ith node and $\phi(\vec{x})$ is an NN. The output layer neurons' biases can be approximated with an additional neuron in the hidden layer with an activation function of $\phi 0(r)=1$. Fig. 7 demonstrates the general architecture of the NN.

The $J1$, $J2$, and $J3$ neurons are used in the input, hidden, and output layers, respectively. $\phi 0(\vec{x})=1$ denotes the output layer's function, whereas $\phi i(\vec{x})$ denotes the hidden nodes' nonlinearity.

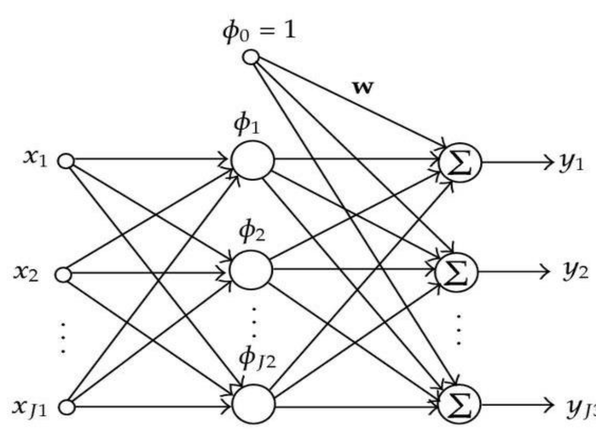

Fig. 7. Architecture of the Neural Network.

V. Experimental Results and Discussion

The purpose of this experiment was to filter and detect patient status as a positive or negative diagnostic of disease. Each sample from the dataset was classified into five groups. Each category had a predetermined sample size (disease cases). Four sets were deemed learning stages, while the remaining one was used as a cross-validation testing dataset. The purpose of this research was to demonstrate the robustness of neural network type prediction and classification when applied to medical information.

As previously stated, the dataset was prepared and tested using the 5-fold cross-validation approach. The examination connected the datasets using the outputs of a neural network classifier in order to assess the strength of NN Types for medical domain diagnosis. The cross-validation approach resulted in the following judgment accuracy outcomes:

$$Accuracy = \frac{(TN+TP)}{(TN+FP)+(TP+FN)} \times 100 \quad (1)$$

True Negative (TN): The number of wrongly identified positive and negative executable; True Positive (TP): The proportion of benign and positive executable that have been appropriately diagnosed; False Negative (FN): The number of positive executable that have been incorrectly classified as negative; False Positive (FP): The number of benign executable that have been incorrectly identified as negative.

In this study, the IBM SPSS modeler software has been used as the machine leaning tool to design our experimental models. The IBM Modeler is the high-performance data mining tool for enterprise. Via an in-depth understanding of data, Modeler enables organizations to strengthen consumer and citizen partnerships. Businesses use Modeler insight to retain successful clients, find cross-selling opportunities, recruit new customers, track fraud, mitigate risk, and enhance government service delivery. The visual interface of Modeler encourages users to apply their domain knowledge, which results in more efficient predictive models and a shorter time to solution. Modeler includes a variety of simulation methods, including algorithms for prediction, sorting, segmentation, and association detection. Modeler Solution Publisher facilitates the enterprise-wide distribution of models to decision makers or to a database after they are developed. The experiments of the investigation study are divided into several steps:

- Step 1: Data collection and preparation from the (UCI dataset).
- Step 2: Divide the dataset into training and testing parts.
- Step 3: Apply different Neural Networks Algorithms (Quick, Dynamic, Multiple, and Radial Basis Function Network (RBFN), Prune, and Executive Prune).
- Step 4: Results analysis.

A. Data Collection and Preparation

- Data collection: In this step, the medical datasets has been collected from University of California Irvine (UCI) Machine Learning data Repository as a source of the datasets. The UCI repository currently maintains 559 datasets as a service to the machine learning community. You may view all datasets through the searchable interface and the following website:
- Data Preparation: We performed pre-processing steps during this procedure, which includes data cleansing, outlier values elimination, and missing values handling (?). The pre-processing has been handled with the following choice based on the dataset description.

1) Delete the corresponding row from the dataset (if the number of missing values in less).

2) Determine the average value for each function and then substitute it for the missing value (numeric values).

3) Counting the number of zeros and ones in each feature and then substitute the highest count values (0 or 1) in the missing value in each feature individually.

- Dataset Descriptions: this section discussed the medical datasets that have been used which are Breast cancer, Chronic Kidney, Diabetes, Parkinson, COVID-19, Epileptic Seizure, HCV, and Heart Disease.
- Breast Cancer Dataset

The breast cancer databases were obtained from the University of Wisconsin Hospitals, Madison from Dr. William H. Wolberg. The description of the dataset is illustrated in Table I.

TABLE I. Breast Cancer Dataset Description

Features Description	No of Samples	No of Features	Machine Learning Task
Integer	699	10	Classification

- HCV (Hepatitis C Virus) Dataset

The data collection includes laboratory results for blood donors and Hepatitis C patients, as well as demographic information such as the age of the patient. The description of the dataset is illustrated in Table II.

TABLE II. HCV Dataset Description

Features Description	No of Samples	No of Features	Machine Learning Task
Real & Integer	615	14	Classification & Clustering

- Parkinson Dataset

The dataset contains a variety of biomedical speech measurements taken from 42 people with early-stage Parkinson's disease who were enrolled in a six-month trial with a digital symptom progression tracking system. Automatic recordings were made in the patients' homes. The description of the dataset is illustrated in Table III.

TABLE III. PARKINSON DATASET DESCRIPTION

Features Description	No of Samples	No of Features	Machine Learning Task
Real & Integer	5875	26	Classification, Clustering, Regression

- Heart Disease

Heart disease database includes 76 attributes; all reported studies make use of a subset of 14. To date, only the Cleveland database has been used by machine learning researchers. The "goal" area indicates if the patient has heart disease. It is an integer number from 0 (no presence) to 4. The description of the dataset is illustrated in Table IV.

TABLE IV. HEART DISEASE DATASET DESCRIPTION

Features Description	No of Samples	No of Features	Machine Learning Task
Real, Integer, Categorical	303	75	Classification

- Diabetes

Diabetes medical records were gathered from two sources: an automated electronic recorder and paper records. The automated system had an internal clock that was used to timestamp events, while paper documents contained only "logical time" slots (breakfast, lunch, dinner, bedtime). Breakfast (08:00), lunch (12:00), dinner (18:00), and bedtime were both set times in paper documents (22:00). Thus, while paper documents contain fictitious standard tracking dates, electronic records contain more accurate time stamps. The description of the dataset is illustrated in Table V.

TABLE V. DIABETES DATASET DESCRIPTION

Features Description	No of Samples	No of Features	Machine Learning Task
Integer, Categorical	100000	55	Classification & Clustering

- Epileptic Seizure

The original dataset from the guide is divided into five directories, each of which contains 100 files, each of which represents a single subject/person. Each file contains a 23.6-second recording of brain activity. 4,097 data points are sampled from the corresponding time sequence. Each data point represents the value of the EEG recording at a certain time point. Thus, we have a total of 500 people, each with 4,097 data points over a period of 23.5 seconds. The description of the dataset is illustrated in Table VI.

TABLE VI. EPILEPTIC SEIZURE DATASET DESCRIPTION

Features Description	No of Samples	No of Features	Machine Learning Task
Real, Integer	11500	179	Classification & Clustering

- Chronic Kidney

The dataset can be used to classify chronic kidney disease and was obtained from a hospital over a period of almost two months. The description of the dataset is illustrated in Table VII.

TABLE VII. CHRONIC KIDNEY DATASET DESCRIPTION

Features Description	No of Samples	No of Features	Machine Learning Task
Integer, Categorical	100000	55	Classification & Clustering

- COVID-19

The X-ray data is saved in the png, jpg, and jpeg formats. Johns Hopkins University uses the two databases from the *Kaggle X-ray* competition as part of their medical database. The comparisons were made between cases with a virus causing bacterial pneumonia, healthy people, and cases caused by COVID19 [46]. One of the photographs in the dataset is of people who have had pneumonia. The COVID X-ray image database was created by Cohen JP using open access images from many different sources. This archive contains a lot of photographs that have been shared with the creators. This archive contains 125 photographs of an X-ray diagnosis of COVID. There are 43 women and 82 men who have demonstrated that they have a certain propensity for creative thinking within the study. Datasets without complete metadata do not include all users. The average age of COVID patients is 55, but the ages of the members range from 26 to 89 years. a database of chestray8 has been developed by Wang et al. [47] in order to compensate for unbalanced images from this series of unbalanced data, we've produced an even distribution of 500 no-finding and 500-frontal chest X-rays that looks random.

B. *Divide the Dataset into Training and Testing Parts*

After the data mining pre-processing steps, we then divide the dataset into two groups. The first group is training data and the data distribution. The investigation models were built based on training and testing dataset. The training dataset was divided into 90, 80, 70, 60, and 50 whereas the testing dataset was divided into 10, 20, 30, 40, and 50 respectively. The training results of the neural network algorithms were examined based on learning groups for each neural network algorithm (Quick, Dynamic, Multiple, and Radial Basis Function Network (RBFN), Prune, and Executive Prune). The accuracy measurement was calculated to examine all the collected medical datasets, including Breast cancer, Chronic Kidney, Diabetes, Parkinson, COVID-19, Epileptic Seizure, HCV, and Heart diseases. Then the average results were computed to select the optimal neural network algorithm for each dataset.

C. *Appling Neural Network Algorithms*

Our investigated study used the neural network algorithms for data prediction to diagnosis different types of diseases. The model was built by selecting the original data after dividing the datasets into training and testing parts. The IBM SPSS Modeler contains six types of neural network algorithms which are: Quick, Dynamic, Multiple, and Radial Basis Function Network (RBFN), Prune, and Executive Prune. The advantage of using the SPSS modeler is that the system applies integration and data visualization in order to show the predicted results explicitly. A sample of investigation model is demonstrated in Fig. 8.

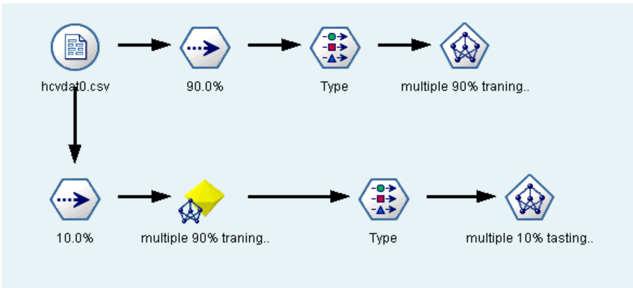

Fig. 8. Sample of Investigation Model using Neural Network Algorithms.

The experimental design process and running procedure has been examined based on the training and testing models.

D. Results Analysis

In the experiments, the medical datasets were used in order to determine the patient (injured or not injured) or predict the diagnosis percentage for some diseases. The dataset had each instance reported as either an injured or not injured case or labelled with target field (Class feature). The neural network algorithm was applied by training and testing the dataset using our investigation models. The main objectives of the learning model in this study is to investigate the diagnosis level by collecting the patients' samples with similar patterns together, thus the variation will be reduced and the diagnosis interpretation will be accurate.

The obtained results of the investigation models have been extracted and analyzed individually for training and testing results. The average results for each algorithm based on the specific disease have been calculated and figured out in different shapes. We noted that the multiple neural network algorithm is better than the other five neural network algorithms in many medical datasets for prediction diagnosis measure. Each fold in the training and testing model is examined with the individual dataset. Fig. 9 to 13 demonstrate the training results of each dataset using different types of neural network algorithms, while Fig. 14 to 18 shown the testing results for accumulated 5 folds cross validation.

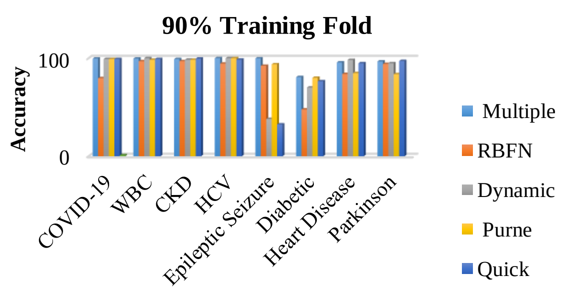

Fig. 9. Training Model with 90%.

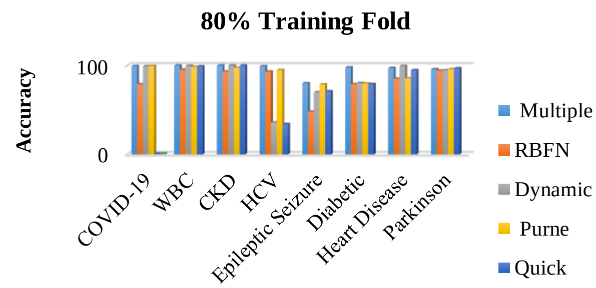

Fig. 10. Training Model with 80%.

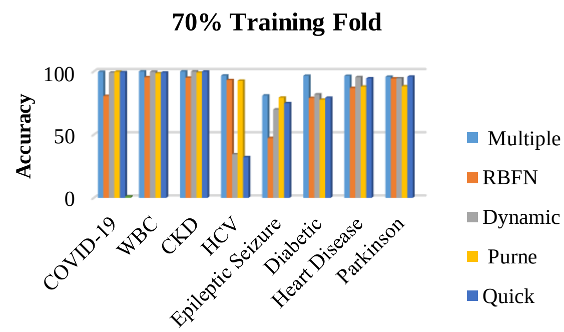

Fig. 11. Training Model with 70%.

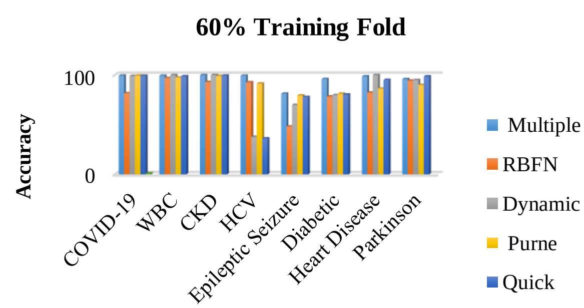

Fig. 12. Training Model with 60%.

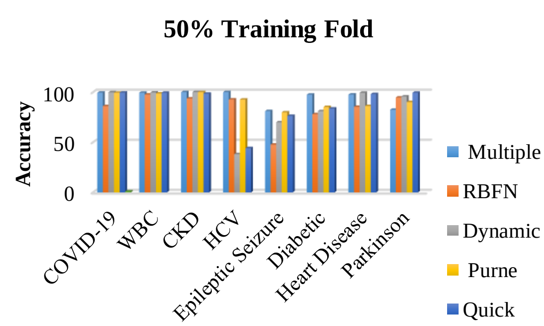

Fig. 13. Training Model with 50%.

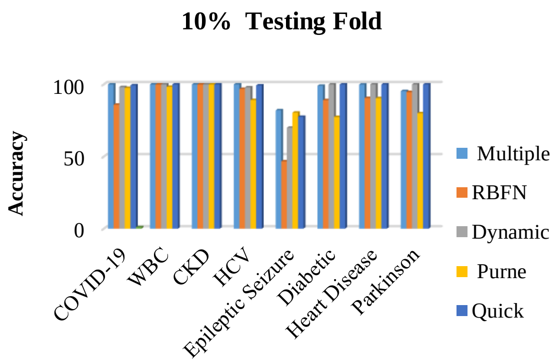

Fig. 14. Testing Model with 10%.

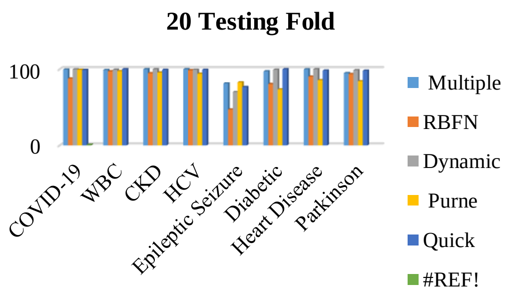

Fig. 15. Testing Model with 20%.

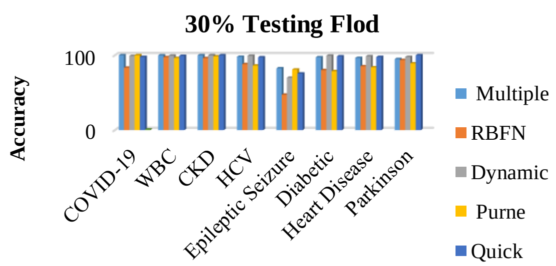

Fig. 16. Testing Model with 30%.

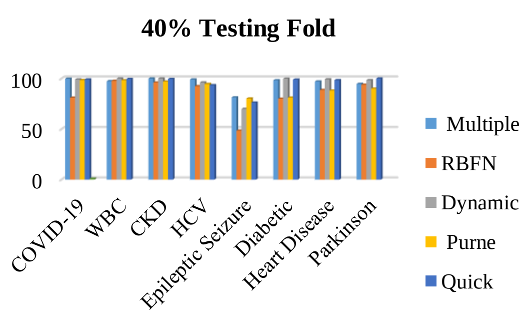

Fig. 17. Testing Model with 40%.

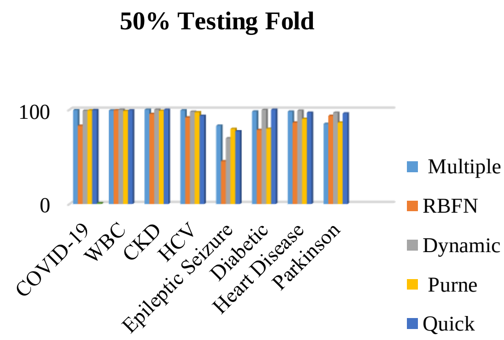

Fig. 18. Testing Model with 50%.

The accuracy of the results of the training and testing model using the five parts folds has been calculated for each dataset using the five main types of the neural network algorithms. Table VIII and Table IX demonstrate the training and testing results for each fold.

The findings of our prediction model trials indicated that neural network algorithms improved performance, and the t-test technique was utilized to quantify the improvement. Low t-test scores (usually less than 0.05) indicate that the two variables have been adjusted significantly. This criterion was emphasized in the assessment measures in light of the diagnosis accuracy values obtained in Table X between the multiple neural network method and the other five neural network algorithms. This demonstrates that Multiple NN outperformed RBFN, and Prune in terms of diagnostic performance. The results of the t-test statistical significance test are shown in Table X.

As shown in Table X, the significant T-test strategy has been applied between the investigated neural network algorithms in this study. We noted that the multiple neural network algorithm achieved significant results less than 0.05 when compared with RBF and Prune algorithms with P-value equal to 0.21 and 0.20 respectively. On the other hand, the Multiple neural network obtained better classification accuracy results as shown in Tables V and IV when compared with Quick and Dynamic algorithms without significant different results under the T-test investigation.

TABLE VIII. FOLD TRAINING RESULTS USING NEURAL NETWORK ALGORITHMS

90 Training Fold					
Dataset	**Multiple**	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	**99.7**	79.6	99.11	99.1	99.18
WBC	99.6	96.9	**100**	98.4	99.21
CKD	99.1	97	98.57	98.4	**99.64**
HCV	**100**	94.5	**100**	**100**	98.54
Epileptic Seizure	**99.8**	92.2	38.05	93.8	32.47
Diabetic	80.77	47.7	70.086	80	76.49
Heart Disease	95.7	83.9	**98.19**	84.8	94.87
Parkinson	96.7	94.1	94.88	83.7	**97.15**
80 Training Fold					
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	99.4	79	99.18	**99.5**	97.72
WBC	**100**	95.4	99.8	98.6	99.1
CKD	**100**	93.2	**100**	97.6	**100**
HCV	**99.3**	93.2	35.9	95.1	34.1
Epileptic Seizure	**80.1**	48	70	78.9	71
Diabetic	**97.9**	79.1	80.3	79.8	79.1
Heart Disease	97.3	85.1	**99.5**	85.5	94.8
Parkinson	95.9	94.4	94.8	96.1	**96.9**
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	99.7	80.6	99.16	**99.8**	99.46
WBC	**100**	95.4	99.802	98.6	99.16
CKD	**100**	95.07	**100**	99.1	99.9
HCV	**96.8**	93.2	34.5	92.7	32.18
Epileptic Seizure	**80.95**	47.3	69.95	79.3	74.88
Diabetic	**96.6**	79	81.87	77.7	79.15
Heart Disease	**96.5**	87	95.53	88	94.57
Parkinson	95.8	94.5	94.57	88.3	**95.9**
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	**99.5**	81.7	99.12	**99.5**	99.34
WBC	99.4	97.1	**100**	97.6	98.83
CKD	**100**	93.03	**100**	99.1	99.5
HCV	**99.4**	92.7	37.78	91.5	36.26
Epileptic Seizure	**81.3**	48.2	69.95	79.5	77.95
Diabetic	**96.1**	78.5	79.86	81.3	80.46
Heart Disease	98.7	82.4	**100**	86.4	95.08
Parkinson	96	94.4	95.07	90.1	**98.71**
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	99.5	86.1	**99.85**	99.4	99.6
WBC	99.4	97.6	**99.71**	98.7	99.43
CKD	**100**	93.7	**100**	**100**	98.44
HCV	**100**	92.7	38.2	92.6	44.11
Epileptic Seizure	**81.1**	47.7	69.95	79.8	76.31
Diabetic	**97.5**	78	81.02	85.2	83.6
Heart Disease	97.6	85.3	**99.37**	86.2	98.07
Parkinson	82.5	94.6	95.7	90.1	**99.4**

TABLE IX. FOLD TESTING RESULTS USING NEURAL NETWORK ALGORITHMS

10 Testing Fold					
Dataset	**Multiple**	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	**100**	85.9	98.14	97.6	99.37
WBC	**100**	**100**	**100**	98.3	**100**
CKD	**100**	**100**	**100**	**100**	99.98
HCV	**100**	96.9	97.97	89.2	99.33
Epileptic Seizure	**82.1**	46.7	69.93	80.4	77.55
Diabetic	99.1	89.1	**100**	77.4	**100**
Heart Disease	99.9	90.6	**100**	90.5	**100**
Parkinson	95.4	94.7	**100**	80	**100**
20 Testing					
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	99.6	87.7	99.76	99.3	99.02
WBC	99	97.3	99.33	97.5	**100**
CKD	**100**	94.8	**100**	95.7	99.29
HCV	**100**	98.7	99.29	94.1	99.28
Epileptic Seizure	81.3	47.2	70.02	**82.7**	76.64
Diabetic	97.3	80.6	99.35	73.6	**100**
Heart Disease	99.9	9.0.4	**100**	85.6	98.27
Parkinson	94.9	93.7	**98.72**	84.2	98.07
30 Testing Fold					
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	**100**	83.4	99.15	**100**	99
WBC	**99.9**	97.5	99.53	96.4	99.35
CKD	**100**	96.2	**100**	98.6	**100**
HCV	98	88.2	**99.41**	86.3	97.56
Epileptic Seizure	**82.6**	47.3	70.05	80.9	75.61
Diabetic	97.3	80.2	**99.55**	78.8	98.6
Heart Disease	96.5	85.4	98.76	84	**98.8**
Parkinson	95	93.6	97.8	89.2	**100**
40 Testing Fold					
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	**99.8**	81	99.19	98.5	99.77
WBC	97.4	97.8	**100**	98.3	99.66
CKD	**100**	96.05	**100**	97	99.61
HCV	**99.1**	92.4	96.96	94.6	97.39
Epileptic Seizure	**82.1**	48.5	69.95	80.2	76.22
Diabetic	98.3	80	**99.86**	81.1	99.02
Heart Disease	97.1	88.66	**99.2**	88.1	98.4
Parkinson	94.7	93.8	98.4	90	**100**
50 Testing Fold					
	Multiple	**RBFN**	**Dynamic**	**Prune**	**Quick**
COVID-19	99.5	83	98.89	99.3	**99.59**
WBC	99.2	97.4	**100**	98.7	99.42
CKD	**100**	95.6	**100**	98.9	**100**
HCV	**99.3**	91.8	97.84	97.3	93.52
Epileptic Seizure	**83.1**	45.4	69.73	79.7	77.16
Diabetic	98.1	78.5	99.74	79.8	**100**
Heart Disease	98	86.4	**98.96**	90.4	96.86
Parkinson	85	93.5	**96.86**	86.4	96.09

TABLE X. T-TEST STATISTICAL SIGNIFICANCE RESULTS

	Differences between the correlation coefficient factor, mean absolute error, root mean squared error, relative absolute error, and root relative squared error before and after the improvement				t	df	P Value
	Mean	Std. Deviation	95% Confidence Interval of the Difference				
			Lower	Upper			
Multiple-RBF	5.6800	3.4339	1.41619	9.94381	3.699	4	.021
Multiple-Dynamic	1.17200	1.66354	-.89356	3.23756	2.785	4	.190
Multiple-Prune	6.98000	4.15295	1.82343	12.3657	3.758	4	.020
Multiple-Quick	1.86400	2.24282	-.92083	4.64883	1.858	4	.137

VI. CONCLUSION AND FUTURE WORK

Machine-learning modelling is analysed to support the provision of the best possible care to all patients with medically relevant data used by millions of healthcare clinicians in decision making for trillions of patients. The speeding up of vast volumes of healthcare data would radically change the structure of the healthcare system. We firmly agree that the relationship between patient and doctor will be the fundamental cornerstone of treatment for many patients and that new developments into machine learning will contribute to this relationship. We expect a few early models, along with the development of regulatory frameworks and economic incentives for value-based services, to be published in the next several years to make us meticulously optimistic about machine education in the field.

This study attempted to analyse medical disease diagnostics in order to modify the prediction method for different types of neural networks. We highlighted the quality of illness prediction models by utilising Quick, Multiple, Dynamic, and RBFN neural network algorithms, as well as prune neural network algorithm. In this study, the experiments conducted were based on different types of medical datasets such as Breast cancer, Chronic Kidney, Diabetes, Parkinson, COVID-19, Epileptic Seizure, HCV, and Heart disease. Our investigation found that the diagnosis results can be predicted and achieved by the neural network algorithms with different types of medical datasets. Additionally, our extensive investigations revealed that the multiple neural network algorithm had the greatest results in terms of diagnostic accuracy for a variety of ailments. In addition, P-value scores have been computed and indicate that the multiple neural network algorithm has significantly better performance compared with other neural Network algorithms. In future work, our research has try to improve all the objectives that were addressed in this study. However, the quality of prediction methods in medical disease has been investigated using neural network algorithms. At some point, this study will plan to apply another types of the neural network algorithms on different medical datasets to achieve high prediction and diagnosis models.

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Optical Character Recognition Engines Performance Comparison in Information Extraction

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***Abstract*—Named Entity Recognition (NER) is often used to acquire important information from text documents as a part of the Information Extraction (IE) process. However, the text documents quality affects the accuracy of the data obtained, especially for text documents acquired involving the Optical Character Recognition (OCR) process, which never reached 100% accuracy. This research tried to examine which OCR engine with the highest performance for IE using NER by comparing three OCR engines (Foxit, PDF2GO, Tesseract) over 8,562 government human resources documents within six document categories, two document structures, and four measurements. Several essential entities such as name, employee ID, document number, document publishing date, employee rank, and family member's name were trying to be extracted automatically from the documents. NER processes were done using Python programming language, and the preprocessing tasks were done separately for Foxit, PDF2GO, and Tesseract. In summary, each OCR engine has its drawbacks and benefit, such as Tesseract has better NER extraction and conversion time with better accuracy but lack in the number of entities acquired.**

Keywords—Named entity recognition; information extraction; optical character recognition; government human resources documents

I. Introduction

Information extraction from scanned documents has been an issue in many countries and domains. Pathel and Bhatt in 2020 [1] used an end-to-end sequential approach for abstractive information extraction on scanned Malaysian invoices. Nguyen et al. in 2020 [2] used a rapid and convenient text-mining method to automatically extract pathology features from complex text-based scanned photocopies of Australian typewritten clinical pathology reports drawn from multiple different sources. Bures et al. in 2020 [3] proposed a system design to extract information from several countries structured scanned invoice documents by an ordinary office scanner device. Rastogi et al. in 2020 [4] used knowledge graph and Formal Concept Analysis (FCA) template detection to extract information from 1,400 scanned trade finance documents. Those issues also have been a problem in Indonesian Government.

In Indonesia, every human resources division in the government has the same problem of extracting information from scanned human resources documents. The information extraction process usually was done manually by entry operators, which is time-consuming and error-prone.

The government's human resources division records a vast number of employee documents each year. For instance, Bogor local government, one of the ninety-eight city governments in West Java, Indonesia, recorded more than 200,000 human resources documents during the 2009 to 2020 period. Those numbers are increasing each year, like in 2018, there are 10,880 recorded documents, while in 2019, the number increased to 28,784 recorded documents. With only two data operators to handle such data, this is really time-consuming, not to mention the human error factor while inserting essential pieces of information from each document into the human resources management system.

This manually extracted information is essential since it has been used for many human resources management system modules like a decision support system for talent management, executive statistics dashboard, salary budget prediction, employee formation, and many others.

Each document was acquired using scanners in PDF format. The recording process was taken manually by operators inserting important information of each document into the human resources database through the human resources management system web-based interface. With the help of IE tasks like NER, this process can be simplified using automated NER to make the data management more effective and efficient.

OCR converts the scanned images of handwritten, typewritten, or printed documents into machine-readable format [5]. IE process is used to extract structured content in entities, relations, facts, terms, and other types of information [6]. In general, NER is a subtask of IE that aims to find and categorize specific entities in text documents [7]. The documents source may vary from the web, generated PDF, and scanned documents in PDF format. In scanned documents case which involves OCR engine, to get good accuracy, precision, and recall of the entities acquired is a challenge for this research.

Three different OCR engines with different environments were selected for the experiment. Foxit as the desktop-based OCR engine, PDF2GO as the web-based OCR engine, and Tesseract as an open-source programable OCR engine. Among those OCR engines, we would like to examine which engine has the highest measurements score to extract essential information from government human resources documents using four measurements.

The measurement results will determine which engine is the suitable solution to handle IE tasks involving NER and OCR process in two document structures. The results will also help any organization to manage scanned documents more effectively and efficiently. As for Indonesian government, an effective and efficient document management would really help any government division to work more efficient with less or even none human resources involved with the help of automated IE from this study.

The following sections of this paper are the related works in Section 2, the materials and methods in Section 3, experiments results and discussion in Section 4. Lastly, the conclusion is in Section 5.

II. Related Work

IE using scanned documents is often noisy and often suffering from blur effects, faded text, watermarks, scanning artifacts, and wrinkles. Those noises often caused the downstream OCR and other errors [4]. Those noises are the cause of low accuracy in IE using scanned documents.

In some cases, preprocessing tasks, such as image contrast improvement, noise reduction, binarization, and image deskewing, are required to get a visual improvement of the scanned documents [3]. High accuracy and low latency for processing large numbers of documents are required to have the best result of OCR [1]. IE in a medical domain has proven that keyword trigger-based automation with OCR correction and negation handling is rapid and convenient and provides consistent and reliable data abstractions from scanned clinical records [2]. Those cases showed that preprocessing has an important role to get a better result in IE using scanned documents.

Taghva et al. in 2006 [8] and Pereda in 2011 [9] proved that the IE task is significantly influenced by OCR errors, while Vijayarani and Sakila in 2015 [10] tried to compare 8 OCR tools using image and PDF documents. NER previous research on PDF documents like legal documents had been done to extract information for specific entities. Solihin and Budi, in 2018 [11], researched the extraction of data from general criminal court decision documents using the rule-based method. Meanwhile, Leitner et al. in 2019 [12] used machine learning methods like CRF (Conditional Random Fields) and deep learning methods like BiLSTM (Bidirectional Long Short-Term Memory) to extract information using NER on legal documents. Nuranti and Yulianti in 2020 [13] also tried the same method in Indonesian legal documents. Those research [11,12,13] used generated PDF legal documents as their data source, while our study used scanned PDF documents which may have lower accuracy influenced by OCR errors.

Tesseract library is often used in several research of IE involving OCR. Patel and friends produced 70% accuracy using 20 sample images in 2012 [14]. Kumar and friends produced 97% accuracy for small scanned bill documents and 83% accuracy for small scanned bill documents using Tesseract OCR on 25 scanned bills in 2020 [15]. Akinbade and friends produced 81.9% character accuracy and 69.7% word accuracy on 11 sample images in 2020 [16]. Haraj and Raissouni produced an average of 95.77% charcater accuracy using tesseract and opencv library over 4 sample images in 2015 [17]. Those research [14,15,16,17] only used relatively small samples (less than 50 documents), while our study used more documents (8,562 documents in 6 Categories and two document structures). Previous research [14,15,16,17], which also employed the Tesseract library, only used string matching to measure the OCR. On the other hand, our study used four measurements, i.e., conversion time, NER time, string match accuracy as precision, and the number of entities acquired as recall.

III. Material and Methods

The proposed method we use in this study is an adaptation of the general framework for text analysis in mining text data literature as shown in Fig. 1 [18]. The framework start with text corpus as an input source, followed by preprocessing phase. Then followed by the text representation process and it ends with the knowledge discovery process as shown in Fig. 1.

Fig. 2 shows the four main phases of the proposed method. The phase began with data collection, followed by the preprocessing step by converting PDF to text. Then, the NER process used rule-based entity recognition written in Python, followed by the end's evaluation process.

The reason we use the prosed method as an adaptation from the general framework for text analysis is because it has suitable phases that also can be implement for IE using NER in this study. Nevertheless the original framework has different examples in each phase since the example is used for text data analytics in social media.

The data collection refers to the text corpus phase, the preprocessing phase is similar, the NER phase refers to the representation phase, and evaluation refers to the knowledge discovery phase.

A. Data Collection

Eight thousand five hundred sixty-two government human resources documents within 6 document categories were collected as data samples. Those documents were downloaded from the human resources server of Bogor local government using PHP script for each document category selected. Table I demonstrates the number of entities and the number of records of each class.

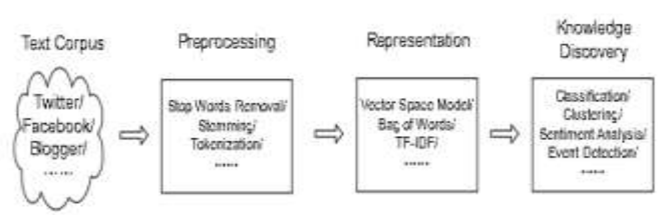

Fig. 1. The General Framework for Text Analysis in Mining Text Data [17].

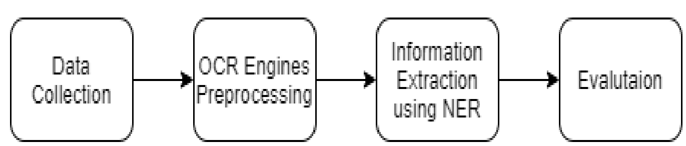

Fig. 2. The Main Phases of the Proposed Method.

TABLE I. DOCUMENTS AND ENTITIES OF EACH DOCUMENT CATEGORY

Category	Average Size	Samples	Entity	Structure
Retirement	505 Kb	110	6	Tabular
Recruitment	448 Kb	453	6	Non table
CV	39 Kb	5,964	7	Tabular
ID conversion	419 Kb	1,168	5	Tabular
Employee position	501 Kb	265	5	Non-table
Family allowance	332 Kb	602	6	Tabular

The category selection was based on the head of National Civil Service Agency regulation number 18 in 2011 about manuscript layout management of the national human resources document [19]. From those categories, four categories (curriculum vitae, ID conversion, family allowance, retirement) have a tabular data structure, and the other two categories (recruitment, employee position) do not have a table data structure.

Each document category has a similar average size and similar number type of entities except for Curriculum Vitae, which has only 39 Kb average size per document. Retirement documents are the fewest, with 110 documents, and Curriculum Vitae is the most significant sample with 5,964 documents.Each document type has at least two same entities: name and employee ID. They are employed as primary keys in the rule-based NER written in Python language to compare the actual values of each entity within the human resources database with the entities acquired from the OCR process results.

The entity selection for each document category were based on the existing information stored in the human resources database. Therefore we can validate and measure the accuracy of each entity acquired by comparing it with the actual value from the human resource database. We used word level accuracy as a measurement for each entity acquired. Therefore we only compare some part of each document as entities with the actual value from the human resources database instead of using the whole text from each document.

Each category has different important entities to extract. Each entity in every type has its own character, as shown in Table II.

TABLE II. RETIREMENT DOCUMENT CHARACTER

Entity	Format
Name	Free text
New ID number	18 digits number
Old ID number	Nine digits number
Document number	Nine digits number + year
Working period	Two digits year and month
Retirement date	dd-mm-YYYY


BADAN KEPEGAWAIAN NEGARA
PETIKAN
KEPUTUSAN KEPALA BADAN KEPEGAWAIAN NEGARA
NOMOR :
KEPALA BADAN KEPEGAWAIAN NEGARA

Fig. 3. ID Conversion Document Sample.


PEMERINTAH KOTA BOGOR
BADAN KEPEGAWAIAN, PENDIDIKAN DAN PELATIHAN
BOGOR - 16123

PETIKAN
KEPUTUSAN WALIKOTA BOGOR
TENTANG
PENGANGKATAN CALON PEGAWAI NEGERI SIPIL
MENJADI PEGAWAI NEGERI SIPIL DARI TENAGA HONORER KATEGORI II
DI LINGKUNGAN PEMERINTAH KOTA BOGOR

WALIKOTA BOGOR

MEMUTUSKAN

WALIKOTA BOGOR

BIMA ARYA

Fig. 4. Recruitment Document Sample.

There are four document types with tabular structure data: retirement, curriculum vitae, ID conversion, and family allowance. There are only two document types with non-table document structures, which are recruitment and employee position.

The following Fig. 3 is an example of an ID conversion document as the tabular structure document, and Fig. 4 is an example of a recruitment document as the non-table structure document.

B. OCR Engines Preprocessing

The next phase after collecting the scanned PDF documents is to convert them into text format. Three OCR engines from three different environments were used in this phase. An offline desktop-based application called Foxit, an online-based application called PDF2GO, and an open-source OCR library called Tesseract were used to convert all documents. Patel et al. in 2012 [14] produce 70% accuracy, Kumar et al. in 2020 [15] produce 97% accuracy and, Akinbade [16] produce 81.9% accuracy using the Tesseract library on scanned documents.

Each engine has its benefits and drawbacks. For Foxit, it has better reading for tabular data and preserves spaces from the original document. However, it has no batch conversion feature. Hence, it must be done manually, one by one. Another drawback for tabular data is the required RTF conversion to get a better result before converting to a TXT file.

On PDF2GO, it has a 500 document conversion per batch feature and supports the Indonesian language feature on the OCR process. However, it does not preserve spacing from the original document, and it takes more time to upload and download the document since it is an online application.

It has unlimited batch conversion on Tesseract since we can customize the process, supporting the Indonesian language OCR process. However, it does not preserve spacing from the original document. The Foxit OCR engine has better OCR quality for tabular data. Still, since it has no batch conversion feature and needs an RTF conversion first before converted to text files, it makes it not efficient in terms of processing time. PDF2GO has 500 documents per batch conversion, and Tesseract has an unlimited document batch. Still, even though it takes 5 to 10 seconds to convert a document for Tesseract, it takes a longer time in PDF2G0 since we have to upload and download the paper first, which consumes more time. In terms of conversion time, Tesseract is the best option. In terms of the OCR feature, Foxit can preserve the space and better handle tabular data. Even though Tesseract included this feature in their library, the page segmentation mode will help extract information from tabular data.

C. Information Extraction using NER

The IE process using NER was written using Python programming language since it has features for NLP tasks. The rule-based method was used since OCR results from the documents are not 100% accurate, unlike the generated PDF documents.

The employee ID number is the primary key used to connect to each entity's other actual value. If we get the wrong OCR result for the employee ID number, it will get the wrong or even empty weight from the human resource database. Each document category from each OCR engine has a different extraction time, as shown in Table III. The table shows that each document category has the various best time for each OCR engine. Foxit has better time records on the retirement category with 0.017 seconds per document and the family allowance category with 0.077 seconds per document. Tesseract has better time records on recruitment category with 0.088 seconds per document, employee position category with 0.0104 seconds per document, and Curriculum Vitae with 0.040 seconds per document. PDF2GO only has a better time record on the ID conversion category with 0.011 seconds per document. On average, Tesseract has the best extraction time with 0.044 seconds per document, followed by PDF2GO with 0.046 seconds per document and Foxit with 0.050 seconds per document.

TABLE III. NER TIME FOR EACH DOCUMENT CATEGORY

Category	**Foxit**	**PDF2GO**	**Tesseract**
Retirement	0.017	0.019	0.023
Recruitment	0.096	0.089	0.088
Curriculum Vitae	0.074	0.071	0.040
ID conversion	0.022	0.011	0.012
Employee position	0.016	0.010	0.010
Family allowance	0.077	0.078	0.092
Average	0.050	0.046	0.044

D. Evaluation

In terms of quality measurement, the string match function from the Python library was used by comparing the entity string acquired with the actual data from the human resources database. This function is based on the G*estalt* pattern matching, which measures accuracy by this equation:

$$D_{\boldsymbol{\gamma}\mathbf{0}} = \frac{2K_m}{|S_1| + |S_2|} \tag{1}$$

The D$\boldsymbol{\gamma}$0 value ranged from 0 to 1, where one value means 100% the same and 0 value means vice versa. The S1 and S2 refer to the character number from the first and second strings, respectively. Km refers to the number of the same character between two strings being compared [20]. We used percentages ranged from 0 to 100 to represent the D$\boldsymbol{\gamma}$0 in our experiment.

The quantity measurement used a simple counter parameter on the rule-based NER Python code each time an entity was acquired. The actual quantity for each entity was obtained using the SQL count function from the human resources database.

IV. RESULTS AND DISCUSSION

A. Results

After the NER process, precision and recall measurement divided for each document category to see which OCR engine text result has better precision, recall, and F1-Score percentages shown in Table IV.

TABLE IV. PRECISSION, RECALL AND F1 MEASUREMENT

Document Type	Structure	Foxit (%)			PDF2GO (%)			Tesseract (%)		
		Precision	Recall	F1-Score	Precision	Recall	F1-Score	Precision	Recall	F1-Score
Retirement	Tabular	93.99	85.06	89.30	93.62	86.58	89.62	88.19	52.42	65.76
Recruitment	Non Table	83.66	73.66	78.34	86.85	92.20	89.45	86.86	90.91	88.83
Curriculum Vitae	Tabular	86.28	86.64	86.46	80.13	97.91	88.13	84.14	80.98	82.53
ID Conversion	Tabular	68.85	84.33	75.81	74.45	77.84	76.11	74.99	54.40	63.06
Employee position	Non Table	87.59	100	93.38	86.46	99.62	92.57	92.8	99.62	96.09
Family allowance	Tabular	95.22	75.87	84.45	92.16	72.84	81.37	91.17	71.42	80.10
Average		85.93	84.26	84.62	85.61	**87.83**	**86.27**	**86.36**	74.96	79.39

Based on Table IV, we can see that in terms of precision by string matching, Tesseract has the highest accuracy with 86.36%. However, in terms of recall, PDF2GO has more identified entities with 87.83%. PDF2GO has the highest F1-Score with 86.27%.

Even though it seems PDF2GO has the highest F1-Score on average, but in terms of document structures, the highest F1-Score are different. Foxit has the highest F1-Score average for tabular data structure with 84.01%, followed by PDF2GO with 83.89% and Tesseract with 72.85%. Tesseract has the highest F1-Score average for non-table data structure with 92.46%, followed by PDF2GO with 91.01% and Foxit with 85.86%.

The results show that the tabular data structure F1-Score average for Tesseract is very low (72.85%). Consequently, it caused the total average of 6 document types also low at 79.39%, even though for non-table data structure Tesseract has the highest F1-Score with 92.46%. Even though Foxit has the highest F1-Score average for tabular data structure with 84.01%, it also has the lowest F1-Score average for non-table data structure with only 85.86%.

In general, PDF2GO has the highest F1-Score average with 86.27%. In terms of tabular document structure, Foxit has the highest F1-Score average with 84.01%. Tesseract has the highest F1-Score average with 92.46% for non-table document structure.

Even though Tesseract has the best precision, however, it has the worst recall. Therefore it also has the worst F1-Score since the precision gap between each OCR engine is slightly different, and the recall gap for Tesseract is far.

In the IE phase, we recorded the processing time of OCR engines for each document category. We can compare which OCR has the best OCR processing time, as shown in Fig. 5.

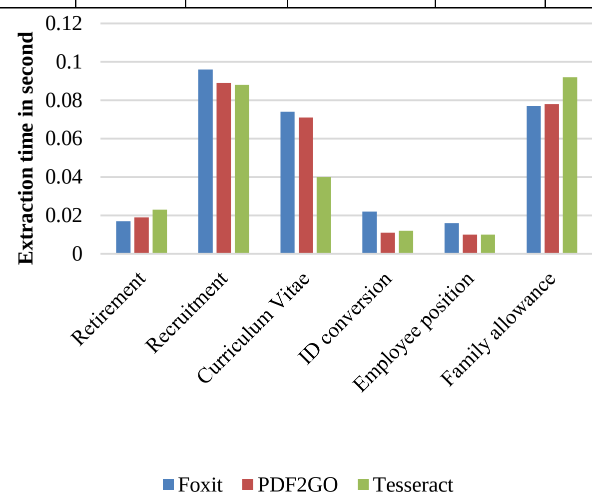

Fig. 5. Extraction Time per Document for each Category.

Tesseract is dominant in three document categories with 0.004 seconds per Curriculum Vitae document, 0.008 seconds per recruitment document, and 0.01 seconds per employee position document. On the other hand, Foxit is dominant in two document categories with 0.017 seconds per retirement document and 0.077 seconds per family allowance document. PDF2GO is only prevalent in one document category with 0.011 seconds per ID conversion document.

On average, Tesseract is the fastest OCR engine with 0.044 seconds per document, followed by PDF2GO with 0.046 seconds per document and Foxit with 0.050 seconds per document. Even though the NER times are slightly different, the impact is enormous since the volume of the document to extract is also enormous. We can say that in terms of NER information extraction time, Tesseract has the best time record, not to mention the benefit of having unlimited batch conversion. In contrast, in Foxit, you have to do the conversion one by one, and in PDF2GO, the batch conversion is limited to 500 documents in the preprocessing phase.

In the precision measurement phase, we recorded the precision of each OCR engine for each document category. Each acquired entity was compared automatically with the actual value from the human resources database records using the *Gestalt* string matching function described previously. From those records, we can compare which OCR has the best string match accuracy, as shown in Fig. 6.

Tesseract has the highest precisions in three document categories with 86.86% in the recruitment category, 92.8% in the employee position category, and 74.99% in the ID conversion category. Foxit has better precision in three document categories with 86.28% in the Curriculum Vitae category, 95.22% in the family allowance category, and 93.99% in the retirement category.Tesseract is more dominant in three documents. Besides, it has the best precision average with 86.36%, followed by Foxit with 85.93% and PDF2GO with 85.61%.

We recorded the number of entities acquired for each OCR engine in each document category in the recall measurement phase. The number of entities acquired for each entity compared to the number of entities in the human resources database using the employee ID number as the primary key. We can compare which OCR has the most entities acquired for the recall measurement from those entity numbers, as shown in Fig. 7.

We can see that PDF2GO has more entities acquired in three document categories, with 86.58% recall in the retirement category, 92.2 % recall in the recruitment category, and 97.91% in the Curriculum Vitae category. Foxit has more entities acquired in three document categories with 84.33% recall in the ID conversion category, 100% accuracy in the employee position category, and 75.87% recall in the family allowance category.

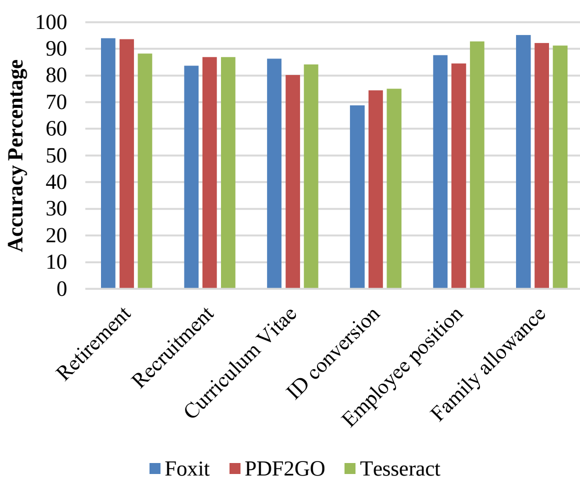

Fig. 6. The Precision Percentage for each Document Category.

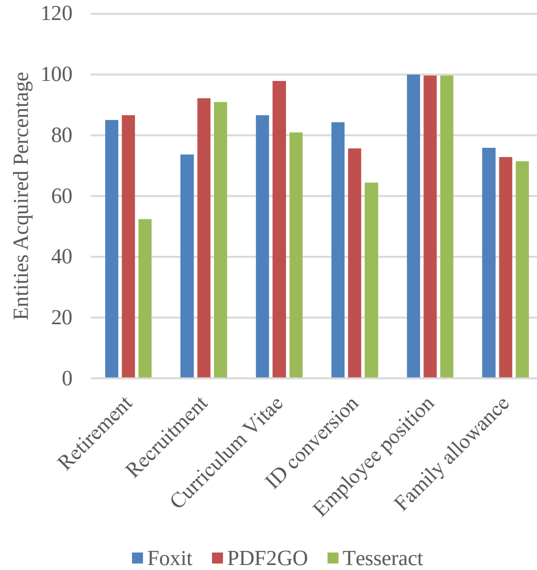

Fig. 7. Recall Percentage for each Category.

Tesseract has the lowest number of entities acquired with only 74.96% recall. PDF2GO and Foxit each have three dominant categories in the number of entities gained. On average, PDF2GO has the highest entities acquired with 87.83%, followed by Foxit with 84.26% and Tesseract with 74.96% entities acquired.

B. *Discussion*

We found a trade-off selection of the OCR engine from the measurements we conducted since Tesseract is good on preprocessing, information extraction time, and accuracy but lacks entity acquirement. On the other hand, PDF2GO and Foxit are dominant for entity acquirement. It lacks accuracy, extraction time, and preprocessing phase since Foxit has no batch conversion feature, and PDF2GO limits the batch conversion of 500 documents per batch.

It shows that Tesseract seems to be the best option for NER in scanned documents regardless of the number of entities acquired. The dominant measurement for Tesseract in preprocessing time, NER time, and precision proved that this OCR engine is reliable to get time efficiency and string match accuracy even though it has a low percentage of recall. The gap between Tesseract and PDF2GO on entities acquired is 13%.

The number of entities acquired is significant since having fast preprocessing and NER time would be meaningless if we have low numbers of information extracted. Writing a better algorithm in rule-based NER, having an automated text normalization, or using deep learning methods for NER might increase the number of entities acquired.

PDF2GO has the best F1-Score with 86.27%, regardless it has a slower NER time with 0.046 seconds per document and slower preprocessing time with 500 documents limit per batch and additional download and upload time to the PDF2GO web.

Even though PDF2GO has the best F1-Score, we found that Foxit has better precision in tabular document structure (retirement, CV, ID conversion, family allowance), as shown in Table IV. For tabular document structure, Foxit has an 84.01% average F1-Score followed by PDF2GO with 83.89% and Tesseract with 72.85%. For non-table document structure (retirement and employee position), Tesseract has the best F1-Score with 92.46%, followed by PDF2GO with 91.01% and Foxit with 85.86%.

Even though the F1, precision, and recall, and OCR engines are less than the previous research [10], we processed many more documents, categories, and documents structure. It consists of 8,562 documents within six categories and two document structures to prove that the OCR comparison using more documents in two different structures may have different results. The previous research [10] only employed string matching as a measurement to compare OCR engine results. In contrast, our study performed at least five measurements, which are preprocessing time, NER time, precision, recall, and F1-Score. Those measurements are more comprehensive than just string matching for an end-to-end information extraction system to manage many documents.

Similar research employed the Tesseract library [16] with only 11 images as input yielding 69.7% precision. On the other hand, our study produced 83.07% precision with 8,562 documents as the same library input. It may not be a fair comparison since the previous research using English text documents while our documents are in the Indonesian language. Tesseract support both English and Indonesian language, therefore even using more variety of document categories and different languages, Tesseract can have a better accuracy result.

Previous research that also performed rule-based NER [11] has 89% F1-Score while our study has 86.27% F1-Score. The preceding experiment employed generated PDF documents with no OCR involves, while ours used scanned documents, and it has the worst text result after the OCR process. In this case, there is a 2.73% gap between scanned documents and generated PDF using the same rule-based NER method. The experiments' results are a potential reference for an end-to-end information extraction system using a vast number of scanned documents involving an OCR engine.

C. Limitations

There are several limitaions on this study such as:

- We had only use tabular and non-tabular document structures in six categories.
- Six document categories were selected from ten available categories based on the head of National Civil Service Agency regulation number 18 in 2011.
- The number of entities for each document category were selected based on esential informations that stored in the human resources database of Bogor local government.
- We only measure the precision through the NER results, therefore we do not use the whole text of the scanned documents since only essential entities such as names, dates, organizations are being extracted and compared to the ground truth from the database.
- We only compared three OCR engines which are Foxit as an offline engine, PDF2GO as an online engine and Tesseract as an opensource engine.

V. Conclusion

This research analyses which OCR engine is the most suitable for IE using rule-based NER written in Python over 8,562 scanned PDF government human resources documents within six document categories. Those categories are retirement, recruitment, Curriculum Vitae, ID conversion, employee position, and family allowance documents with tabular and non-tabular structures. Involving more document structures such as watermark and handwriting scanned documents may have a better data representation for future research.

Three OCR engines from three different environments were compared during the experiment. Foxit as an offline desktop OCR engine, PDF2GO as an online OCR engine, and Tesseract as a free and open-source multiplatform OCR engine library. Tesseract is the most suitable solution in terms of preprocessing since it provides an unlimited document conversion batch. Tesseract is also the fastest OCR engine in NER extraction time; nevertheless, numbers of entities acquired Foxit and PDF2GO are more dominant on three documents each. In terms of string match entity accuracy as precision, the Tesseract OCR engine is dominant on three document categories.

On average, PDF2GO has the highest F1-score (86.27%). In terms of tabular document structure, Foxit has the highest F1-Score (84.01%). Tesseract has the highest F1-Score (92.46%) for non-table document structure. Those scores show that Tesseract is more suitable for non-table documents and Foxit is more appropriate for tabular documents.

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Higher Order Statistics and Phase Synchronization as Features in a Motor Imagery Paradigm

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***Abstract*—The paper proposes an approach based on higher order statistics and phase synchronization for detection and classification of relevant features in electroencephalographic (EEG) signals recorded during the subjects are performing motor tasks. The method was tested on two different datasets and the performance was evaluated using k nearest neighbor classifier. The results (classification rates higher than 90%) have shown that the method can be used for discriminating right and left motor imagery tasks as an offline analysis for EEG in a brain computer interface system.**

Keywords—Brain computer interface; motor imagery; higher order statistics; phase synchronization; EEG

I. Introduction

The brain computer interface (BCI) system has aroused a real interest, as it has become an important tool in translating the measured brain activity into control commands.

The BCI was developed for biomedical applications, which led to the development of assistive devices for restoring movement and communication force for patients with disabilities. The use of electroencephalography (EEG) in the state-of-the-art of brain-computer interface technology has expanded to enhance quality of life, with medical and non-medical applications [1]. Various BCI innovations, such as the BCI wheelchair [2], spellings, BCI exoskeleton [3], BCI prosthesis, BCI robot [4] and others are the result of this huge interest in BCI [5].

The electroencephalogram is a source of information often used in BCI because it records the electrical activity of the brain with the help of the attached electrodes on the scalp. The BCI system amplifies the collected signals, notifies these changes and transforms them into control signals for communication or control of external equipment. BCI allows patients with paralysis or motor disorders to have an alternative method of communication and control.

Compared with other existing neuroimaging modalities, electroencephalogram has higher time resolution, portability, availability, and, so it is more commonly used.

EEG based BCI systems are centered on several paradigms [6-7]: Steady State Visual Evoked Potential (SSVEP), P300, Slow Cortical Potential (SCP) and Motor Imagery (MI). Motor imagery implies imagination of hand/arm/finger/foot movement. More precisely, motor imagery is the translation of the motor intention into control signals for a BCI device. After imagination, event-related synchronization (ERS) and desynchronization (ERD) are produced over the sensorimotor cortex region [8]. Brain activity recorded via EEG is classified into five different rhythms: Delta (0-4 Hz), Theta (4-7 Hz), Mu (8-12 Hz), Beta (12-30 Hz), Gamma (30-70 Hz). Mu and Beta rhythms are associated with actions like preparation and movement of limbs.

Methods like autoregressive model [9], independent component analysis [10], wavelet transform [11] have been applied in order to extract relevant features contained in the EEG signal while a motor imagery task was performed.

The aim of the paper is to propose a combination of features which includes higher-order statistics (HOS) based on bispectrum and bicoherence and phase synchronization based on phase locking value and phase lag index. The features can be used for discriminating motor tasks in a motor imagery paradigm.

In Section II the handled datasets are described and Section III presents the methods, features extraction and classification. Section IV belongs to results and Section V to conclusions.

II. Datasets Description

Dataset I contains EEG signals acquired in our laboratory. The brain activity was recorded using a gMobilab+ module [12] and BCI 2000 platform [13]. Dataset II was downloaded from the internet [14]. Table I presents the information regarding the manipulated datasets.

TABLE I. DATABASES SUMMARY

Database information	**Dataset I**	**Dataset II**
Number of subjects	57	9
Channels	C3, C4, CP3, CP4, P3, P4, Cz	
Number of Trials	60	90
Sampling frequency	256 Hz	100 Hz
Paradigm description	On a monitor screen right and left arrows were displayed. The subjects had to perform the motor task indicated by the arrow (left hand and right hand motor imagery).	

III. Methods

Higher order spectra are expressed in terminologies of higher order statistics such as moments and cumulants of a random process, in this case EEG signals [15-16].

Bispectrum is commonly applied in the biomedical area mainly for EEG signal processing. Bispectrum is d in the bi-frequency domain [15]:

$$B(f_1, f_2) = E[X(f_1)X(f_1)X^*(f_1 + f_2)] \quad (1)$$

where $X(f)$ is the Fourier transform of a windowed portion of a single realization of the EEG signal $x(nT)$, n is an integer index, T is the sampling period and $E[.]$ represents the expectation operation.

Bicoherence is given by the following relationship [15-16]:

$$B_{norm}(f_1, f_2) = \frac{E[X(f_1)X(f_1)X^*(f_1+f_2)]}{\sqrt{P(f_1)P(f_2)P(f_1+f_2)}} \quad (2)$$

where $P(f)$ is the power spectrum of $x(nT)$.

When the oscillatory phases from two brain regions are correlated the phase synchronization appears. The phase synchronization from the motor imagery period is different from the phase synchronization in the relaxation period so it can be exploited by BCI applications [17].

Large scale synchronization appears between brain signals acquired from electrodes located in the primary motor area and from electrodes located in the additional motor area.

Phase locking value (PLV) [17] and phase lag index (PLI) [18] are calculated in order to detect changes in the large scale synchronization and in order to measure the synchronization between two signals $x(t)$ and $y(t)$.

PLV represents the lastingness of the phase difference between instantaneous phases $\varphi_x(t)$ and $\varphi_y(t)$:

$$PLV = \left|\langle e^{j\Delta\varphi(t)}\rangle\right| \quad (3)$$

$$\Delta\varphi(t) = \varphi_y(t) - \varphi_x(t)$$

The phase lag index is defined by:

$$PLI = |\langle sign[\Delta\theta(t_k)]\rangle| \quad (4)$$

$sign$ is the signum function and $<.>$ denotes the time average.

A. Data Processing for Higher Order Statistics

Two sets of data were formed: one related to right hand movement imagery and the other corresponding to left hand movement imagery.

First, the EEG signals aquired from channels C3, C4, CP3, CP4, P3, P4 when the subject imagined the right hand movement were segmented in 30 (Dataset I) and 45 (Dataset II). The bispectrum and bicoherence were estimated using functions from HOSA toolbox [19]. Two different frequency ranges were extracted for analysis in the bi-frequency plane (f1 – f2): Mu – Mu, Beta – Beta. The module of the bispectrum was calculated for these frequency ranges. In the next step only the elements above the main diagonal (those below the main diagonal being equal to those above) were extracted for the two frequency ranges.

A direct method is applied to estimate the bicoherence.

Four quantity measures for each frequency range were settled: the sum of the bispectrum modules, the sum of the squares bispectrum modules, the sum of the bicoherence modules, the sum of the squares bicoherence modules.

The steps described above were followed for the EEG signals corresponding to left hand motor imagery.

B. Data Processing for Phase Synchronization

Four sets of data were created: the right hand movement imagery, the rest after right hand movement imagery, the left hand movement imagery and rest after left hand movement imagery. In order to compute PLV and PLI, the instanteneous phase of the EEG signals must be determined. The instanteneous phase of the EEG signals is computed using Hilbert transform. The Hilbert transforms were calculated for the EEG channels mentioned.

One electrode from the auxiliary motor imagery area, Cz, three electrodes from the right hemisphere, C4, CP4, P4 and three electrodes from the left hemisphere, C3, CP3, P3 were utilized in order to establish the combinations. The completed pairs of electrodes were: Cz-C4, Cz-CP4, Cz-P4, Cz-C3, Cz-CP3, Cz-P3. The differences between PLVs of the rest period and motor imagery period were formed for the above pairs of electrodes.

The steps mentioned above were repeated for PLI.

C. Feature Vectors

Nine feature vectors were created by bringing together two, three or four of the already mentioned measures. So, the first feature vector is formed by bicoherence and PLV, the second by bicoherence and PLI, the third by bicoherence, PLV and PLI, the fourth by bispectrum and PLV, the fifth by bispectrum and PLI, the sixth by bispectrum, PLV and PLI, the seventh by bicoherence, bispectrum and PLV, the eighth by bicoherence, bispectrum and PLI and the ninth by bicoherence, bispectrum, PLV and PLI. These nine feature vectors were named according to their way of grouping: *Bicoherence_PLV* was attributed for the feature vector combining bicoherence and PLV, *Bicoherence_PLI* for the feature vector merging bicoherence and PLI, and so on.

The discrimination between right and left motor imagery was evaluated with k nearest neighbor (kNN) [20]. The performance of classifier was assessed through classification rate, sensitivity and specificity. The classification rate, the specificity and the sensitivity are characterized using the following terms: true positive (TP), true negative (TN), false negative (FN) and false positive (FP) [21]:

$$Classification\ rate = \frac{TN+TP}{TN+TP+FN+FP} \quad (5)$$

$$Sensitivity = \frac{TP}{TP+FN} \quad (6)$$

$$Specificity = \frac{TN}{TN+FP} \quad (7)$$

IV. RESULTS

In Fig. 1 is displayed the bispectrum of an EEG signal corresponding to right hand motor imagery for channel C3 (Dataset I) and Fig. 2 illustrates the bispectrum of an EEG signal corresponding to left hand motor imagery for channel C4 (Dataset I). The bicoherence of an EEG signal corresponding to right hand motor imagery for channel C3, respectively the bicoherence of an EEG signal corresponding to left hand motor imagery for channel C4 are shown in Fig. 3 and Fig. 4.

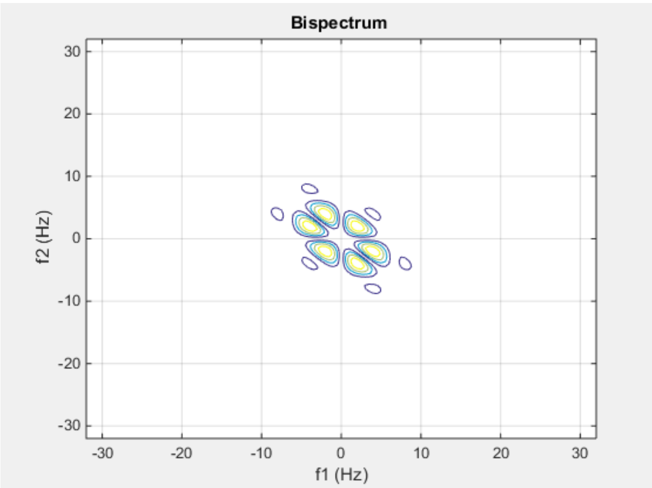

Fig. 1. The Bispectrum of an EEG Signal Corresponding to Right Hand Movement Imagery for Channel C3 - Datatset I.

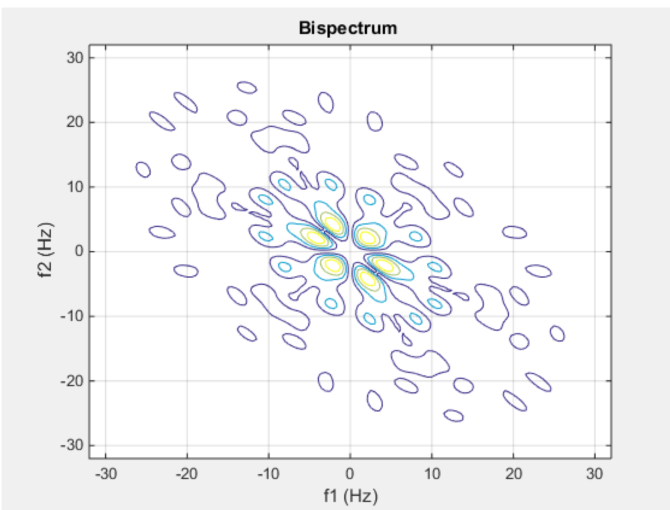

Fig. 2. The Bispectrum of an EEG Signal Corresponding to Left Hand Movement Imagery for Channel C4 - Datatset I.

From the above figures we can see that the bispectrum and the bicoherence yielded to different graphs for EEG signal corresponding to right versus left hand motor imagery and this suggests that can be used as feature vectors for classification.

Fig. 5 shows the box plots for the classification rate, the sensitivity and the specificity using as feature vectors Bicoherence_PLV, Bicoherence_PLI and Bicoherence_PLV_PLI for Dataset I. The highest value (90%) of the median for classification rates was obtained for Bicoherence_PLV_PLI and all the subjects attained classification rates in the range 84% to 94%.

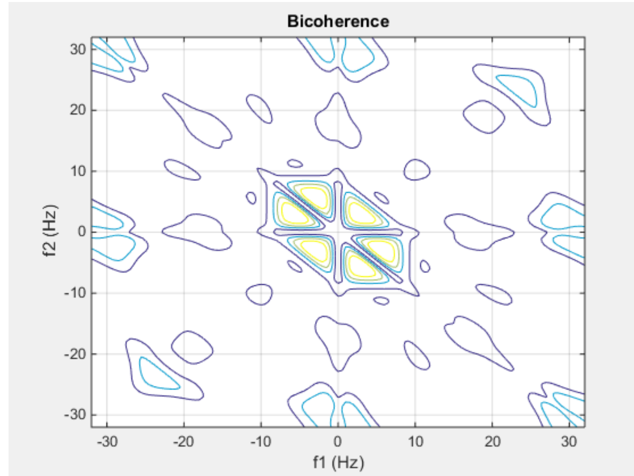

Fig. 3. The Bicoherence of an EEG signal Corresponding to Right Hand Movement Imagery for Channel C3 - Datatset I.

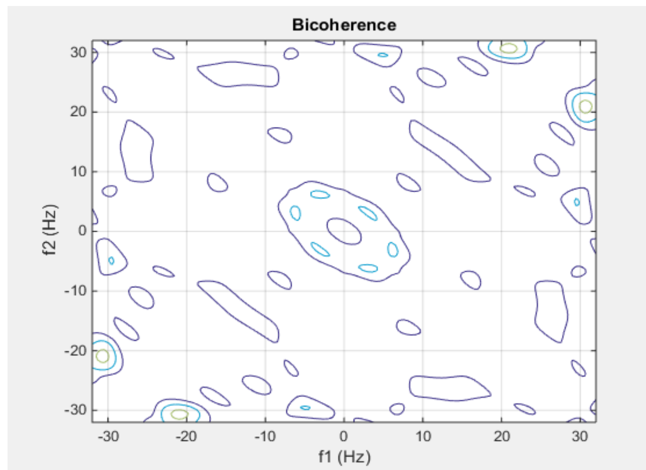

Fig. 4. The Bicoherence of an EEG Signal Corresponding to Left Hand Movement Imagery for Channel C4 - Datatset I.

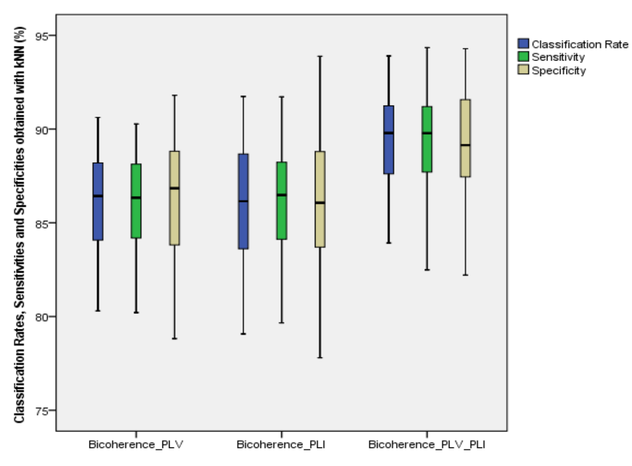

Fig. 5. The Box Plots for Classification Rate, Sensitivity and Specificity using Feature Vector Bicoherence_PLV, Bicoherence_PLI and Bicoherence_PLV_PLI – Dataset I.

The box plots for the classification rate, the sensitivity and the specificity using as feature vectors Bispectrum_PLV, Bispectrum_PLI and Bispectrum_PLV_PLI - Dataset I are displayed in Fig. 6. The medians for the classification rates, the sensitivities and the specificities obtained were above 88% for Bispectrum_PLV_PLI. The outliner marked in blue color represents the highest classification rate attained (the value isn't relevant since belongs to a single subject).

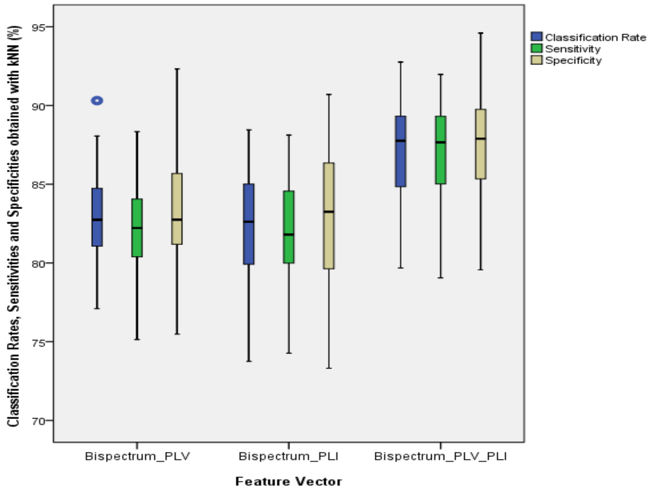

Fig. 6. The Box Plots for Classification Rate, Sensitivity and Specificity using Feature Vector Bispectrum_PLV, Bispectrum_PLI and Bispectrum_PLV_PLI - Dataset I.

In Fig. 7 are presented the box plots for the classification rate, the sensitivity and the specificity using as feature vectors Bicoherence_Bispectrum_PLV, Bicoherence_Bispectrum_PLI and Bicoherence_Bispectrum_PLV_PLI – Dataset I. The highest classification rates, sensitivities and specificities were realized for Bicoherence_Bispectrum_PLV_PLI.

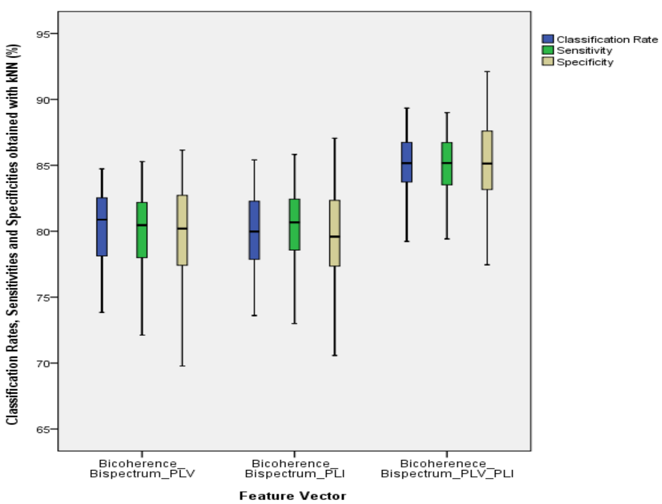

Fig. 7. The Box Plots for Classification Rate, Sensitivity and Specificity using Feature Vector Bicoherence_Bispectrum_PLV, Bicoherence_Bispectrum_PLI and Bicoherence_Bispectrum_PLV_PLI – Dataset I.

Fig. 8 shows the box plots obtained for the classification rate, the sensitivity and the specificity using as feature vector Bicoherence_PLV, Bicoherence_PLI and Bicoherence_PLV_PLI - Dataset II. The highest classification rates were for Bicoherence_PLV_PLI. The outliners marked with "*" for all the figures are for Subject 9.

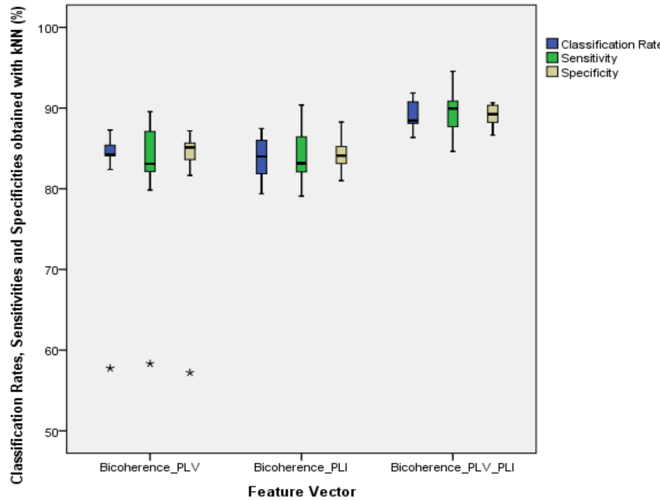

Fig. 8. The Box Plots for Classification Rate, Sensitivity and Specificity using Feature Vector Bicoherence_PLV, Bicoherence_PLI and Bicoherence_PLV_PLI - Dataset II.

Fig. 9 displays the box plots achieved for the classification rate, the sensitivity and the specificity using feature vector Bispectrum_PLV, Bispectrum_PLI and Bispectrum_PLV_PLI - Dataset II. Overall, the best classification rates (85%), sensitivities and specificities were obtained for Bispectrum_PLV_PLI .

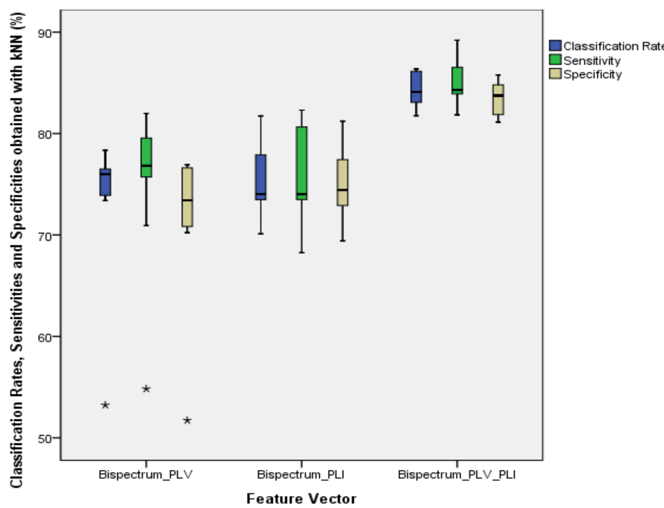

Fig. 9. The Box Plots for Classification Rate, Sensitivity and Specificity using Feature Vector Bispectrum_PLV, Bispectrum_PLI and Bispectrum_PLV_PLI - Dataset II.

The box plots for the classification rate, the sensitivity and the specificity using as feature vector Bicoherence_Bispectrum_PLV, Bicoherence_Bispectrum_PLI and Bicoherence_Bispectrum_PLV_PLI – Dataset II are presented in Fig. 10. Comparing to the other feature vectors, the smallest classification rates, sensitivities and specificities were obtained for the feature vectors from Fig. 10.

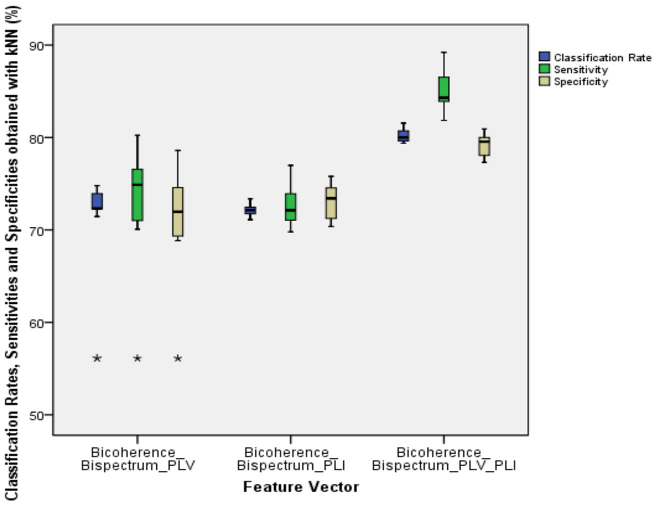

Fig. 10. The Box Plots for Classification Rate, Sensitivity and Specificity using Feature Vector Bicoherence_Bispectrum_PLV, Bicoherence_Bispectrum_PLI and Bicoherence_Bispectrum_PLV_PLI – Dataset II.

In Table II are summarized the maximum and the median of the classification rates for Dataset I and Dataset II attained with the mentioned feature vectors. The best classification rates were attained for feature vector *Bicoherence_PLV_PLI* for both datasets.

In [22] where a framework for achieving subject transfer strategy is proposed, the classification rates obtained for subject 9 were in the range 57.93% to 70.93% with linear discriminant analysis. The results are consistent with the results obtained with our feature vectors.

In [23] where was investigated a method based on multiple frequency spatial synthesized features with support vector machine classifier, the classification accuracies were smaller than the results reported in this paper.

TABLE II. THE MAXIMUM AND THE MEDIAN CLASSIFICATION RATES FOR THE FEATURE VECTOR USED – DATASET I AND DATASET II

Feature Vector	Dataset I		Dataset II	
	Classification rate			
	Max	Median	Max	Median
Bicoherence_PLV	90.62%	86.43%	87.28%	84.08%
Bicoherence_PLI	91.74%	86.15%	87.45%	84.00%
Bicoherence_PLV_PLI	93.90%	89.79%	91.86%	88.44%
Bispectrum_PLV	90.31%	82.74%	78.35%	76.00%
Bispectrum_PLI	88.45%	82.79%	81.73%	74.04%
Bispectrum_PLV_PLI	92.76%	88.15%	86.37%	84.11%
Bicoherence_Bispectrum_PLV	84.73%	80.88%	74.79%	72.31%
Bicoherence_Bispectrum_PLI	85.41%	79.98%	76.39%	72.28%
Bicoherence_Bispectrum_PLV_PLI	89.34%	85.71%	83.08%	79.70%

In [24], [25] were manipulated only PLV and PLI without being in combinations with other methods, but more channels were taken into account. The results achieved in these two cited works are approximately the same with the results stated in this paper with feature vector *Bicoherence_PLV_PLI*. The maximum classification rates of 86% are attained using PLI and SVM classifier.

V. CONCLUSION

An offline analysis was performed on two datasets that contained 57 subjects and 9 subjects. Using combinations of bispectrum, bicoherence, phase locking value and phase lag index, nine features vectors were formed.

By means of Bicoherence_PLV_PLI as feature vector and kNN as classifier, the highest classification rates, sensitivities and specificities achieved for Dataset I were 93.90%, 94.35% and 94.29% respectively and for Dataset II were 91.86%, 94.56% and 90.67%, respectively.

The best classification rate attained with Bicoherence_PLV_PLI for both datasets highlights that, regardless of the database and of the conditions in which the electroencephalographic signals were recorded, the grouping of the three measures that compose this feature vector discriminates the best the two classes. The explanation might be linked to the fact that there are taken into account both the information of nonlinear interaction described by bicoherence and of the large scale synchronization described by PLV and PLI, and together they discriminate better than alone the two tasks.

The subjects from Dataset II were trained and the subjects from Dataset I were untrained. Even if the subjects from Dataset II were trained, the results obtained were worse than those for Dataset I. This fact suggests that the method used for creating feature vector *Bicoherence_PLV_PLI* is adequate to be used for discrimination of motor imagery tasks in a BCI, no matter the degree of subjects' training.

The future work implies testing the method on other available datasets that provide EEG signals recorded from the subjects while performing motor imagery tasks.

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Enhanced Framework for Big Data Requirement Elicitation

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***Abstract*—Requirement engineering is one of the software development life cycle phases; it has been recognized as an important phase for collecting and analyzing a system's goals. However, despite its importance, requirement engineering has several limitations such as incomplete requirements, vague requirements, lack of prioritization, and less user involvement, all of which affect requirement quality. With the emergence of big data technology, the complexity of big data, which is defined by large data volume, high velocity, and large data variety, has gradually increased, affecting the quality of big data software requirements. This study proposes a framework with four sequential phases to improve requirement engineering quality through big data software development. By integrating the proposed framework's phases in which user requirements are collected in a complete vision using traditional requirement elicitation techniques with agile methodology and mind mapping, the collected requirements are displayed via a graphical representation using mind maps to achieve high requirement accuracy with connectivity and modifiability, enabling the accurate prioritization of requirements implemented using agile SCRUM methodology. The proposed framework improves requirement quality in big data software development, which is represented by accuracy, completeness, connectivity, and modifiability to understand the value of the collected requirements and effectively affect the quality of the implementation phase.**

***Keywords*—Requirement engineering; big data requirement; agile methodology; mind mapping**

I. Introduction

Software requirement engineering represents business needs and goals, including functional and nonfunctional dependency competencies that must be represented and achieved. Several issues in the requirement engineering life cycle have contributed to a high failure rate for software engineering projects, such as the lack of comprehensive requirements, including unclear, incomplete, and inaccurate requirements; requirement conflict, leading to insufficient estimation of social and technological requirements; the lack of customer involvement, leading to customer dissatisfaction; and concurrent changes in requirements [1]. Nowadays, the development of big data software applications is prevalent. According to big data technology market analysis [2], "The big data market size is projected to grow from USD 138.9 billion in 2020 to USD 229.4 billion by 2025, at a compound annual growth rate of 10.6% during the forecast period." With the increasing growth of data, defining the term "big data" has become more challenging when considering big data characteristics such as volume, which refers to the quantity of data generated; velocity, which refers to the speed at which data are generated; and variety, which refers to different types of data generated (e.g., text, documents, video, audio, and images). Consequently, requirement challenges have increased because representing a huge volume of data and determining the exact time that data will be received and how long they will take to arrive are essential factors to consider. Additionally, it is critical to determine the type of data received because each data type has its customization, so considering these characteristics in the requirement election phase became more challenging [3]. Big data characteristics pose severe challenges to achieving software requirement quality standards for security, performance, scalability, privacy, and other quality requirements. Additionally, how to systematically handle quality requirements involving big data characteristics to better understand the requirements of big data software projects is a challenge [4]. A well-planned framework for the requirement elicitation process can mitigate the negative effect of big data software requirement limitations. Mind mapping provides the best practice in requirement election representation on the basis of its graphical concept, i.e., mapping the main ideas together to obtain the best value, producing an accurate and clear requirement representation while considering big data characteristics and quality attributes, which greatly aids in obtaining well-prioritized requirements. Nowadays, agile SCRUM methodology has gained popularity because of its properties, such as flexibility, which can handle the technical issues mentioned above, as it handles changes in requirements, customer involvement, and satisfaction, besides documenting the requirements in the product backlog [5]. Although agile is the commonly used methodology in big data projects because of its resilience in accepting new and changes in requirements during the implementation process, big data project needs more optimized methodologies to deal with the massive changes of requirements especially in big data project considering its characteristics. So, by the integration with mind mapping, it'll help develop a prioritized product backlog, as agile SCRUM is the initial requirements specification document [6].

In summary, focusing on the entire process of requirement elicitation for big data software projects, not only on better requirements but also on the quality of the elicited requirements, is an excellent way to set the stage for accurate software development.

This paper proposes a framework for requirement elicitation that comprised four phases: a collection phase, mind mapping phase, prioritization phase, and agile phase, all the phases were explained in Section IV. The integration of these phases provides a complete and accurate path for requirement gathering that will help a system analyst team elicit, analyze, and manage requirements for a big data software project. The framework serves the requirement elicitation and analysis phase in the big data projects development life cycle, and it promotes the achievement of high-quality big data requirements during this stage. It's necessary to place a strong emphasis on achieving quality factors that are highly supportive of the big data characteristics of completeness, correctness, connectedness, and modifiability in order to meet the needs for large volume, velocity, and variety of data.

The following parts are organized into five sections. The background of this research is presented in Section II. In, Section III, the literature review is presented. In Section IV, the methodology is provided. The framework implementation is discussed in Section V. Conclusions are presented in Section VI.

II. Background

This research is an integration of different parts, including requirement elicitation, big data, agile methodology, and mind mapping, and each part will be introduced in the following sections.

A. Requirements Elicitation

First, requirement elicitation is considered to be one of the most critical activities in the software development industry [7]. It defines a project scope by gathering requirements, which are considered stakeholders' needs, and merging this information to produce a meaningful and understandable method for developing a system that will meet these needs.

Several empirical studies have discussed requirement engineering challenges in the software development life cycle [8]. These challenges have been traced and collected under two main aspects, which are customer and system aspects, as shown in Fig. 1. The two aspects are interdependent, as challenges from the customer aspect, such as a lack of understanding of users' needs, customer collaboration, and a common language, lead to challenges in the system aspects, such as requirement changes and updates and a lack of accurate documentation, requirement quality, and requirement prioritization.

The first step in eliciting requirements from a customer is to understand what the customer wants because interactions with customers typically occur in a natural language, which makes it difficult to obtain complete and clear requirements, and the second step is to engage with the customer to gain a better understanding of the elicited requirement; however, because of the lack of customer collaboration, understanding customer needs and requirement clarification is hampered [9]. Changing requirements during the development process causes loss of system requirement objectives, increases cost and time, and necessitates a continuous update to the stored requirement documentation. Additionally, storing requirements in the form of user stories in a system backlog is not an appropriate solution to fully understand the system requirement and track updates on it according to the agile development life cycle [10]. Prioritizing requirements according to specifics factors such as business value, risk, importance, cost, dependency, and constraints becomes more challenging in a complex system [8]. The above challenges significantly affect requirement quality, especially when dealing with complex projects such as big data projects, as we have discussed in this study. Hence, the main objective of this study is to improve requirement quality, thereby improving the functionality and services provided to end-users.

B. Requirement Engineering and Big Data Projects

With the ubiquity of emerging technologies such as big data and the Internet of Things, the processes of software engineering, such as requirement gathering, design, implementation, and testing, must be evolved and improved to apply these new technologies [11].

Specifying the requirement engineering processes must be improved in the context of big data projects, as the process complexity has increased because of the existence of several dynamic components, such as distributed networks, databases, business intelligence layers, middleware, and computation node, making requirement election in this complex distributed environment extremely difficult [12]. Additionally, data scientists and software engineers face difficulty when measuring and determining the maximum value of big data.

The main big data characteristics include volume, velocity, and variety. Volume is the size of data, which are generated from different data sources. Velocity is the data speed. Variety is the data type, including structured, semi-structured, and unstructured data, such as text, image, audio, and video. Recent research has claimed that the above-mentioned big data characteristics are the most effective factors that affect the quality of big data projects because it is extremely difficult to provide system requirements with high quality standards, such as performance, security, accuracy, availability, and reliability [13].

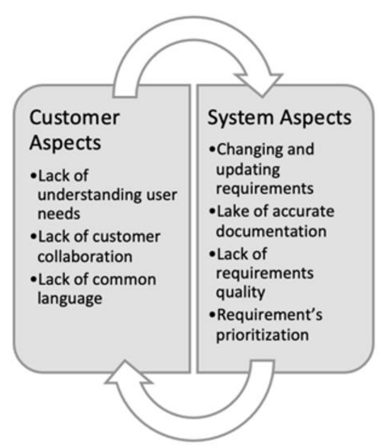

Fig. 1. Requirement Engineering Challenges.

C. Agile and Big Data Projects

A Project Management Institute Report stated that more than 70% of companies have adopted an agile approach, concluding that agile projects are 28% more effective than traditional ones [14]. The requirement elicitation for big data software applications using agile methodology is not easy and straightforward. A detailed requirement is required in the software development life cycle, but agile focuses on less documentation, neglecting quality requirements, difficulties with communication in distributed teams, and quick processing, which can lead to skipping necessary user requirements [5]. Customer satisfaction is the only evidence that requirements are complete and comprehensive, and agile methodology provides many ways to keep the customer involved. However, more customer involvement without any knowledge regarding nonfunctional requirements and experience in the project field lowers the likelihood of project success [15]. Requirement prioritization is a critical issue that can increase cost and time estimation [16].

Different agile methodologies include SCRUM, Kanban, Extreme Programming, Agile Unified Process, and Adaptive Software Development. This research focuses on SCRUM because of its advantages [14].

SCRUM follows agile development process principles as its highest priority is to gain customer satisfaction through all development stages [17]. SCRUM uses short iterations called sprints, which occurs every 2 or 4 weeks. New requirements are developed until the project is completed in each sprint, as shown in Fig. 2. The figure shows the workflow of SCRUM methodology, starting with the product backlog, which includes the prioritized requirement list that has been estimated and added according to the business value of a product owner; then, the team adds a few requirements to the sprint backlog and decides how to implement them. Afterward, the development team starts to implement those requirements through sprints, which occur every 2–4 weeks. They also meet in a daily SCRUM meeting to assess the progress of the project. At the end of a sprint, the developed requirements could be delivered to stakeholders. In the next sprint, the same process, starting again from selecting some requirements from the product backlog to delivering the requirements to stakeholders.

In SCRUM methodology, changes in requirements or technologies are always welcomed at any stage of the development process; however, concurrent changes in requirements negatively affect the entire cycle of software development [14] [17], as well as requirement prioritization, which may increase cost and time estimation [18]. In this case, integrating mind mapping and SCRUM methodology is the most effective, as it helps in obtaining understandable and detailed prioritized requirements, which will significantly and positively affect the software development cycle, as demonstrated in the following section.

D. Mind Mapping

Mind mapping is a technique representing a system's main ideas hierarchically, which helps a team organize, visualize, and generate new ideas, considering the entire aspects of the system [19].

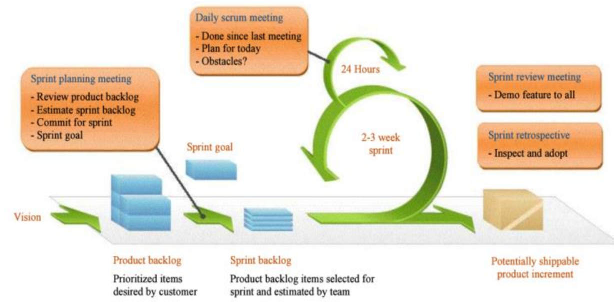

Fig. 2. SCRUM Methodology [35].

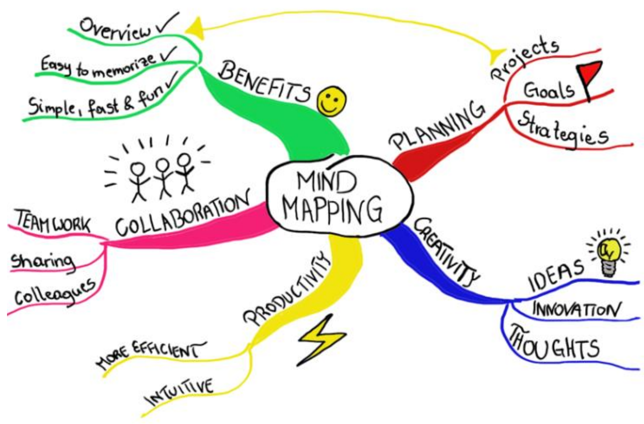

Fig. 3. Mind Mapping Diagram [20].

Mind mapping is performed by placing the most relevant concept in the center of a diagram and connecting it to other concepts, as shown in Fig. 3. This figure is an example of how to represent information in mind maps using multiple layers, and these layers are divided according to the project's requirements.

Mind mapping aids capturing requirements in multiple layers. When collecting data, this results in high quality and accurate requirements by involving stakeholders in the requirement engineering process. This aids in gaining a better and deeper understanding of the overall system's requirements [19]. Mind mapping is a well-known graphical representation concept that can be used on paper or any other tools to most appropriately and accurately represent a system's goal, obtaining complete requirements with their objective value and assisting in obtaining highly prioritized requirements to be implemented [18]. Mind mapping, with its advantages, helps in enhancing a system's requirement quality, which significantly and positively affects the development process and its success. Additionally, integrating mind mapping with SCRUM methodology significantly improves the overall quality of the product backlog.

III. Related Work

Several studies have been conducted on big data requirement elicitation, as it is a new topic that has attracted researchers' attention in recent years. However, little success has been accomplished in this area, which includes the phases of the requirement engineering process, requirement types, application domains, requirement engineering research challenges, and solutions suggested by requirement engineering research in the context of big data applications [10]. The authors in [21] proposed an artifact model that can capture the main requirement elicitation components and their relationship with the development of big data software applications. In [22], a model was proposed that can engage software engineers and data scientists to discover software requirement processes with their business values for big data software using a use case diagram.

The main objective of this study is to obtain high quality requirements. The authors in [4] presented an approach that specifies quality requirements in the context of big data systems by considering requirement engineering challenges in big data projects. The main idea is to intersect big data characteristics with quality attributes and then identify the system's quality requirements on the basis of that intersection. This proves that big data quality characteristics are mapped to quality requirement specifications. There have been some research papers published on the use of an agile methodology in big data system development to mitigate the challenges of big data system developments. The authors in [23] studied the possibility of applying an agile methodology to big data projects. They gathered information by interviewing experts in big data projects from various organizations. Data are analyzed to determine which agile manifesto concepts can be used to manage big data projects. They have recommended using an agile approach to big data management. In [24], the authors proposed an architecture-centric agile big data analytics development methodology. This architecture enables stakeholders to collaborate effectively to evaluate the importance of the proposition for the system in development and to concentrate on more critical tasks such as value validation. In [25], the authors claimed that in big data analytics using agile methodology, there are three phases. The planning phase is the phase in which the system's stakeholders, goals, and requirements are identified and documented by the product owner in a user story that is prioritized on the basis of independent features. The development phase is the phase in which data are collected according to users' needs, which are then analyzed, and requirements are developed to discover the system's goals and objectives. The closure phase occurs when all requirements are implemented and tested. In [26], the authors studied and analyzed agile methodologies to determine the best practice of business intelligence in big data. They introduced an agile framework that addresses big data's effect on business intelligence using two layers. The first layer comprises five steps (discovery, design, development, deployment, and value delivery) to achieve business goals. The second layer consists of six steps (scope, data acquisition/discovery, analysis, visualization, validation, and deployment) for data analysis and deployment. The two layers are combined to ensure the framework's implementation and management. In [14], a method was proposed for enhancing the quality of the requirement gathering process by combining I*organizational models with standard agile SCRUM methodology; however, because of the complexities of big data projects, it will necessitate additional research.

There are several techniques for requirement elicitation, and the mind mapping technique is the most appropriate for completely and effectively representing the collected requirements and it is effective in large-scale and big data systems [15]. The authors in [27] concluded that the requirement engineering processes (elicitation, analysis, specification, validation, and requirement management) are considered in the development of mind maps and revealed that only functional requirements are considered during the development of mind mapping maps in requirement engineering, with no evidence to consider nonfunctional requirements. In [19], the authors proved the contribution of the mind map development to the software agile methodology results in a high-quality derived product backlog, so mind mapping was recommended for setting up a proper product backlog with agile development methodology such as SCRUM.

According to the above studies, to enhance the quality of big data system's requirements, the best practice for achieving high quality requirements is to integrate requirement gathering election techniques with mind mapping and SCRUM methodology.

IV. Methodology

In the following section, the proposed framework has been introduced in detail with its integrated sequentially phases. The framework is divided into four main sequential phases, as shown in Fig. 4.

This figure depicts the proposed framework flow, starting with the requirement collection phase, which helps in gathering requirements from stakeholders to gain complete and understandable requirements reflecting the project's scope, aim, and objectives, as described in Section A. The output of this phase is a valuable input to the next phase, which is the mind mapping phase, where all collected requirements will be graphically represented in mind maps, and based on mind mapping and its representation, it will be an added value to obtain the best practice in mapping the collected requirements under the appropriate quality attribute and big data characteristics, as described in detail in section B. In this phase, all requirements will be identified, which will help in identifying functional and nonfunctional requirements for the desired big data project. The output of this phase will be input into the prioritization phase. In this phase, requirements are prioritized on the basis of the business needs and other aspects that will be introduced in section C. Finally, prioritized requirements will be added to the SCRUM product backlog, as shown in Section D.

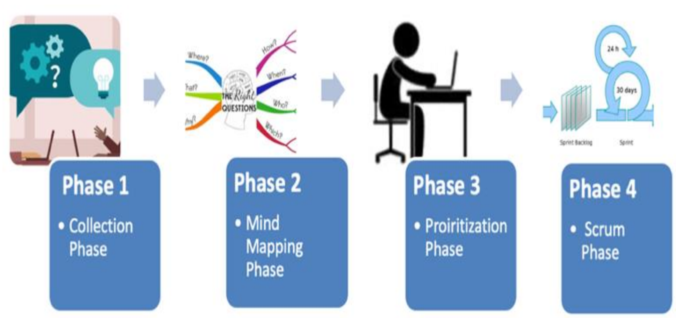

Fig. 4. Proposed Framework Phases.

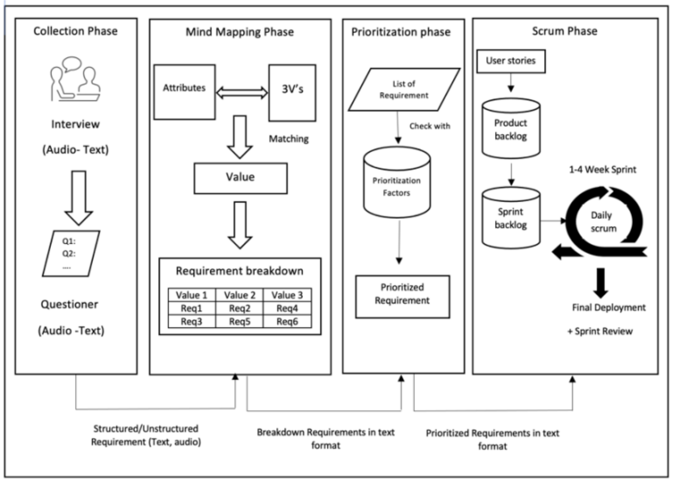

Fig. 5. Framework Methodology.

In the following sections, detailed steps at each phase in the proposed framework are described, as shown in Fig. 5. The steps at each phase are briefly described, and it is demonstrated how beneficial the output of each phase is to the quality of the next phase.

A. Collection Phase

In the collection phase, all system requirements are collected and specified. Requirement gathering is divided into two steps, each using one of two main requirement elicitation techniques, which are the interview and questioner techniques. The interview technique is extremely effective and useful for gaining full and precise information regarding system requirements, and through the feedback, errors in requirements can be easily found and explained. The interview with stakeholders is based on questions and answers and open discussions, so during the interview, organizational goals, needs, and objectives are identified. Additionally, system users' needs and constraints are identified. Thus, well-defined and organized requirements are identified during the interview, and the interview is recorded and typed in a natural language format to be accessible after the interview. Results from the interview are verified, analyzed, and broken down into clear and understandable points and questions. The requirements are converted into a questionnaire form, then it will be shared with the stakeholders in the second requirement collection step, which is the questioner technique. Presenting all requirements in the form of a questionnaire will gain a better understanding and confirmation of the identified requirements. The outputs of the collection phase are fed into the mind mapping phase, which helps in visualizing complete requirements with high quality.

B. Mind Mapping Phase

In the mind mapping phase, the most precise requirements are categorized and represented to achieve high quality requirements for big data systems. With the benefits of mind mapping graphical representation and considering big data characteristics, the mind mapping representation is considered the best practice for achieving quality requirements for big data systems. Hence, the objective of mind mapping is to represent the collected requirements under a permutation of big data characteristics, such as volume, velocity, and variety, and quality attributes, such as performance, security, accuracy, availability, and reliability, to achieve the requirement value, as shown in Fig. 6.

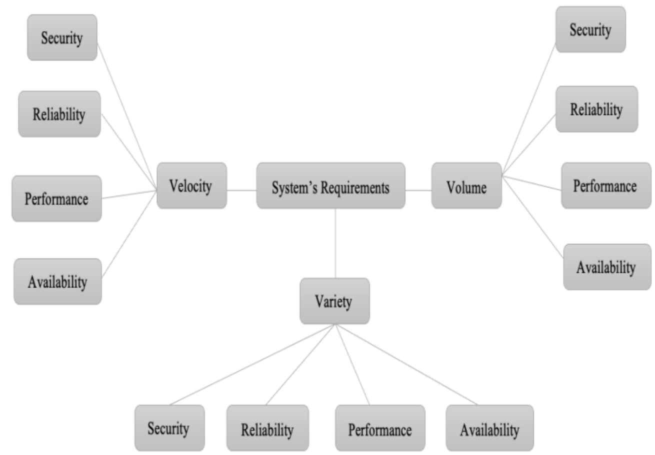

Fig. 6. Mind Mapping Phase Representation.

The figure depicts the division level of mind mapping branches. The first branch level will represent big data characteristics. The second branch level will represent quality attributes. The third branch level will represent all collected requirements from the collection phase. Through two steps, all collected requirements are broken down. In the first step, each big data characteristic will be matched with quality attributes on the basis of the output of requirements of the collection phase. Thus, big data characteristics can be matched with one or more quality attributes according to the big data quality requirement description and goals. In the second step, the collected requirements are matched under each permutation, as discussed in the first step, and shown in the example below.

> "System users initiate 10,000 transactions per minute for normal system operations, and these transactions are processed in an average latency of two seconds."

Here, in the above example, the requirement will be added to velocity and performance branches, and the related requirements will be added to these branches as well.

In this phase, all requirements are presented and described without any missing, duplicate, or incomplete information. However, even when new requirements or changes in requirements are added, they will be easily added to the appropriate branch. This will also help in deciding when and how the new requirement will be implemented. Mind mapping has a good visualization effect for the collected information, as it provides users with an in-depth insight to avoid any missing details, and all functional and nonfunctional requirements will be defined.

C. Prioritization Phase

In the prioritization phase, after the requirements are defined and mapped in the mind mapping diagram, the requirements are prioritized using MoSCoW technique. Based on the MoSCoW technique advantages which are handling a large number of requirements and it is the ease of use and scalable [28]. MoSCoW technique helps in identifying which requirement is mandatory and which is out of scope. By its feature, all the gathered requirements from the mind mapping phase will be assigned under four priority categorize; M is a must-have category in which all the mandatory requirements are assigned so any missing in these requirements will cause a system failure, S is a should-have category in which all the high priority requirements are assigned that can't be postponed, C is a could-have category in which all second priority requirements are assigned, and W is a wont-have category in which assigned requirements will not be implemented in the current development phase and will be implemented in the future.

All the requirements are categorized based on the required evaluation criteria such as business value, which represents the importance of the requirement and how it will affect the organization's needs; profits, which will affect system efficiency if not considered as a priority or necessitate further changes after implementation, thereby affecting the estimation time and cost; importance, that is, implementing the important requirements first always leads to customer satisfaction; cost, that is, selecting requirements according to its importance based on the budget, as budget is one of the system constraints; and dependency, that is, some requirements depend on others, so it is critical to avoid the disorganization of the dependencies, and constraints, which is if developers should research new technologies this will affect the project cost and time [29]. This categorization will highly affect in the next phase in which it will help product owner to select the most effective features to be implemented.

D. SCRUM Phase

In the SCRUM phase, prioritized requirements are added to the product backlog, which is used for documenting the entire system's requirements as user stories. The advantage of the prioritization phase is that it helps the product backlog obtain well-identified and prioritized requirements, which helps in making a good decision on which requirements will be added first to the product backlog to efficiently implement the collected requirements using SCRUM methodology.

V. Implementation

An evaluation study has been conducted on the proposed framework through a set of big data software companies in different application domains to assess the quality of the requirements that followed the proposed framework phases. Conducting a set of surveys for the project's key roles of system analysts team lead, developer team lead, and quality team leads assessing the output's credibility and effectiveness by analyzing survey results. In this section, the evaluation study has been conducted in three steps, i.e., planning, action, and output.

A. Planning

The planning step aims to identify how to conduct the evaluation study using sequential steps to obtain an effective result for the proposed framework. The sequential steps begin by identifying the business limitations that will be improved within the proposed framework, followed by preparing the survey questions to which participants will respond according to their technical viewpoint, and finally, identifying the appropriate participant to assist in conducting the evaluation study.

1) Identify business limitations: In the first sequential step, the main objective of the framework is to mitigate these limitations and obtain the system's requirements with high quality. Thus, requirement elicitation limitations have been investigated and observed through the literature review, and the quality factors that have to be addressed are selected and categorized into two parts. The first part includes accuracy and completeness in which the proposed framework aims to achieve requirements with fewer missing details, and conflict requirements, and considering big data characteristics, namely, variety, volume, and velocity, in the requirement specifications because specifying all the related requirements will improve the development cycle and testing cycle as well. The second part includes connectivity and modifiability in which the proposed framework aims to accept any new requirement or any change in the requirement smoothly continuously, and all requirements are connected to generate more understandable and linked requirements, which prioritize the requirements in an effective way that will aid in the development cycle.

The requirement elicitation limitations have been classified under each quality factor part, as shown in the next section.

2) Prepare survey questions: Survey questions mainly evaluate the requirements that passed all phases of the proposed framework using four quality factors: requirement accuracy, requirement completeness, requirement connectivity, and requirement modifiability. These factors are related to the common limitation in the requirement elicitation process. The requirement accuracy goal is to obtain requirements that demonstrate the extent to which data accurately characterize the real project and accurately represent all of its elements and aspects. The requirement completeness goal is to obtain complete requirements that contain all essential information, including constraints and conditions, that will help implement the requirements that meet the project's needs. The requirement connectivity goal is to obtain requirements that are linked together, and each word, definition, characteristic, and element is specified and linked as an entire set. The requirement modifiability goal is to obtain a requirement hierarchy that enables the creation of any new requirement or change in the requirement to be applied completely and consistently while also avoiding any duplication or redundancy in requirements.

The survey questions are divided into two main sections. The first section includes seven questions to evaluate the current company's framework used by the company. Thus, participants will respond to the survey questions, which indicate how far these limitations are a problem in the followed framework. The second section includes nine questions to evaluate the proposed framework. Hence, participants will respond to the survey questions, which show how far these limitations are still a problem. The survey questions contain multiple-choice responses and one open-ended question. The multiple-choice responses range from 0 to 5, where 0 means strongly disagree and 5 means strongly agree. The open-ended question is general feedback on the proposed framework. A briefly described document has been prepared about the proposed framework, which participants use as a manual guide whenever they need more details while answering the survey questions.

3) Identify participants: Identifying participants from big data software projects with their different roles, including system analyst leads, developer leads, and quality leads, as they are the key persons of any project, and their participation in the research based on their technical expertise will have a significant impact on assessing the proposed framework. In this regard, we contacted approximately 20 big data software companies. A request will be sent to all participants to respond to the designed survey's questions according to their technical experience. Responses will be analyzed and converted into a statistical representation showing how far the limitations are a problem before and after applying the proposed framework.

B. Action

The survey questions and descriptive documents were distributed among the three main roles at the 20 selected companies. Direct communications have been established with the three roles to provide them with additional clarifications regarding the proposed framework and to assist them in implementing all its phases.

C. Output

Fifteen companies agreed to participate in the study, but some of them did not accept announcing their affiliation because of company constraints. Two other companies declined to participate because of company constraints, and the other three companies did not respond. The responses have been analyzed on the basis of two sections, which are responses on the current company's framework, and responses after applying the proposed framework.

1) Participant responses based on the current framework: The participants' responses have been analyzed and represented, as shown below in Table I. The first row lists the seven questions. Q1: How far was the conflict in requirements a problem in your project? Q2: How far was the missing requirement a problem in your project? Q3: How far was the data variety of big data requirements identified using your current project? Q4: How far did the requirement specifications identify data with huge volume and velocity (speed of the received data)? Q5: How complete and consistent was the change in requirements? Q6: How far are the collected requirements linked together and understandable? Q7: How effective was prioritizing the requirements in the implementation phase?

Then, the first column includes the response scores ranging from 0 to 5, where 0 means strongly disagree and 5 means strongly agree. The second column contains the participants in which SATL denotes the system analyst team lead, DTL denotes the developer team lead, and QTL denotes the quality team lead.

The responses are represented as the total number of responses from each participant in each role for each question.

As shown in Table I, the responses identified the extent of the limitations in the software companies, as conflict and missing requirements are still considered an issue in the current working framework. Most of the participants' responses were between 3 and 5, indicating that they strongly agreed on the missing requirements and the requirement conflict. The requirements with their big data characteristics (volume, velocity, and variety) are unspecified, and this is based on the participants' responses, with the average response ranging from 1 to 3. The efficiency of changing any requirement constantly is still a research gap based on the participant's responses, which are ranged from 1 to 3.

Fig. 7 shows the average responses from all companies' participants' roles based on the company's' current framework.

TABLE I. RESPONSES BASED ON THE CURRENT FRAMEWORK

Score	Role	Q1	Q2	Q3	Q4	Q5	Q6	Q7
0	SATL							
	DTL					1		
	QTL			1		2	1	1
1	SATL			4	8	3	1	1
	DTL			4	2	5	1	4
	QTL			6	3	8	2	4
2	SATL	5	3	6	2	4	4	3
	DTL	1	2	7	8	5	5	4
	QTL		2	6	7	3	8	4
3	SATL	1	2	5	3	7	4	4
	DTL	4	2	4	4	3	6	7
	QTL	5	3	2	4	2	3	6
4	SATL	7	5		1		5	3
	DTL	7	4		1	1	3	
	QTL	4	5		1		1	
5	SATL	2	5		1	1	1	4
	DTL	3	7					
	QTL	6	5					

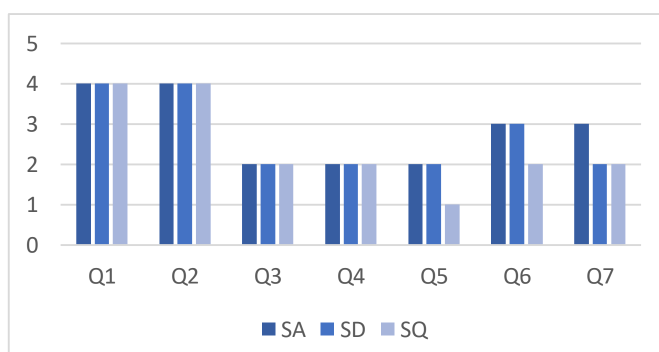

Fig. 7. Average Participant Responses for the Current Framework.

2) Participant responses after using the proposed framework: The participants' responses have been analyzed and illustrated, as shown below in Table II. The first row lists the eight questions. Q1: How far was the conflict in requirements still a problem in your project? Q2: How far was the missing requirement still a problem in your project? Q3: How far was the data variety of big data requirements identified within the proposed framework? Q4: How far did the requirements specifications identify the data with huge volume and velocity (speed of the received data) within the proposed framework? Q5: How complete and consistent was the change made in requirement using the proposed framework? Q6: How far were the collected requirements linked together and understandable using the proposed framework? Q7: How far prioritizing the requirements are applied effectively in the implementation phase within the proposed framework? Q8: How far did the elicited requirements specify the required technologies and tools that should be used, and the absolute constraints to the project using the proposed framework? Q9: Open questions on the participant comments and feedback. Then, the first column contains the response scores, which is ranged from 0 to 5, where 0 means strongly disagree and 5 means strongly agree. The second column contains all participants, where SATL denotes the system analyst team lead, DTL denotes the developer team lead, and QTL denotes the quality team lead. The responses are represented as the total number of responses from each participant in each role for each question.

TABLE II. RESPONSES BASED ON THE PROPOSED FRAMEWORK

Score	Role	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
0	SATL	6	3	1	1				
	DTL	4	9						
	QTL	5	3						
1	SATL	4	7	1	1				
	DTL	7	5	1					
	QTL	6	7						
2	SATL	1	2	1		2			
	DTL	3	1						
	QTL	3	4						1
3	SATL	2	1	1	2	1	2	1	2
	DTL								1
	QTL	1	1		1				
4	SATL	1	1	3	4	9	2	5	6
	DTL	1		8	7	6	7	5	8
	QTL			7	6	8	8	9	7
5	SATL	1	1	8	7	3	11	9	7
	DTL			6	8	9	8	10	6
	QTL			8	8	7	7	6	7

As illustrated in Table II, the responses demonstrated the effectiveness of the sequential phases of the proposed framework on mitigating the software requirement limitation, so conflict and missing details in requirements are identified in the second phase of the proposed framework on the basis of the participants' responses, which ranged from 0 to 3 that strongly disagree with limitation existence and the participants' feedback as well. Using mind mapping, all requirements related to big data characteristics are identified in an understandable and connectable way, allowing for changes in requirements and effective prioritization of requirements.

Fig. 8 represents the average responses from all companies' participants' roles based on the proposed framework.

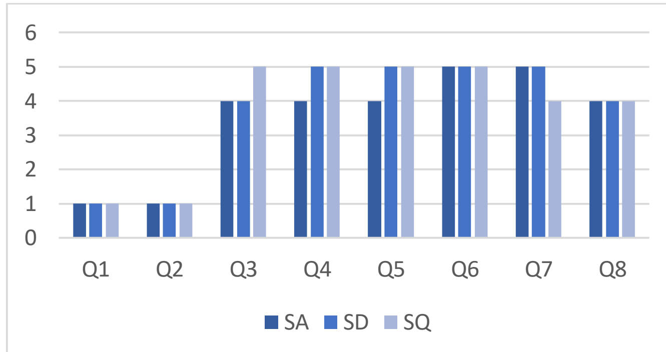

Fig. 8. Average Participant Responses for the Proposed Framework.

The survey questions are formulated to measure the four quality factors, which are divided into two parts:

3) Part 1: Completeness and accuracy are represented by Q1, Q2, Q3, and Q4: Survey question responses for the first four questions indicate that the completeness and accuracy of requirements become more realistic and consider the entire main aspects and elements of the project, which primarily applies to the big data project. When comparing the participants' responses before and after applying the proposed framework, requirement completeness and accuracy were improved by more than 50% of the current situation, as shown in Fig. 9.

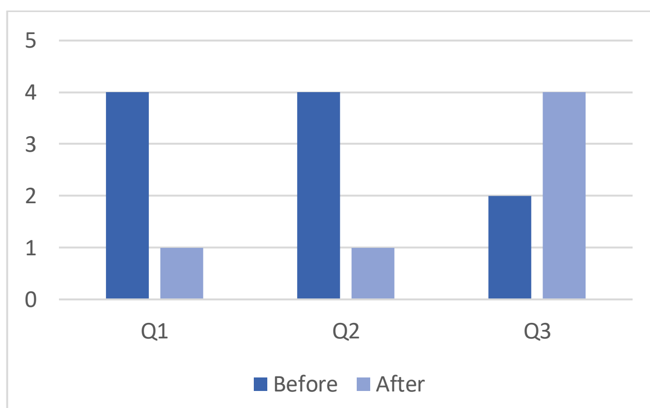

Fig. 9. Comparative Analysis between, before and after applying the Proposed Framework.

4) Part 2: Connectivity and modifiability are represented by Q4, Q5, Q6, Q7: Survey question responses for the three questions indicate that the connectivity and modifiability of the requirements help in mapping and linking the requirements together in an understandable and clear scenario; additionally, by identifying big data characteristics, the required technologies and tools that will be used and the absolute constraints applying to the project are specified. When comparing the participants' responses before and after using the proposed framework, the requirement connectivity and modifiability were improved by more than 30% of the current situation, as shown in Fig. 10.

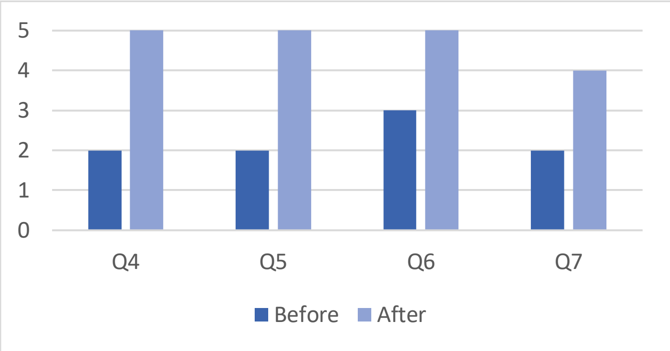

Fig. 10. Comparative Analysis between, before and after using the Proposed Framework.

VI. Conclusion and Future Work

Requirement engineering is the most crucial stage in the software development life cycle, and more attention should be given to its limitations, such as incomplete, unclear, and conflict in requirements. The complexity of collecting accurate requirements and achieving high quality of the collected requirements becomes more challenging when considering big data characteristics. Representing the huge volume, velocity, and variety of the data in the big data project requirements is the main reason to increase the complexity. An integrated framework with four different phases is proposed; each phase works independently to get the best results for the next phase to improve the requirement engineering process in big data software development. Collection phase is using traditional requirement elicitation techniques to clearly identify all the system requirements from the stakeholder. Mind mapping phase map all the collected requirements under big data characteristics and the quality attributes. The prioritization phase helps to identify requirements under four categories; server, high priority, less priority, and not required to classify which bulk of requirements should be developed first and which should be postponed. SCRUM phase to efficiently implement the big data project requirements. A survey was conducted with industry experts to validate the proposed framework on the basis of their technical background, in which the survey question is assessing the output performance before and after applying the proposed framework. The survey results prove the usefulness of the proposed framework in obtaining high-quality, complete, and detailed requirements for big data projects.

In the future, the proposed framework will be extended and verified to handle different phases in the software engineering process like the design, and the testing phase. Each phase will require different big data characteristics and different big data quality factors need to be achieved.

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Analyzing Predictive Algorithms in Data Mining for Cardiovascular Disease using WEKA Tool

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***Abstract*—Cardiovascular Disease (CVD) is the foremost cause of death worldwide that generates a high percentage of Electronic Health Records (EHRs). Analyzing these complex patterns from EHRs is a tedious process. To address this problem, Medical Institutions requires effective Predictive Algorithms for the Prognosis and Diagnosis of the Patients. Under this work, the current state-of-the-art studied to identify leading Predictive Algorithms. Further, these algorithms namely Support Vector Machine (SVM), Naïve Bayes (NB), Decision Tree (DT), Random Forest (RF), Artificial Neural Network (ANN), Logistic Regression (LR), AdaBoost and k-Nearest Neighbors (k-NN) analyzed against the two datasets on open-source WEKA software. This work used two similar structured datasets i.e., Statlog Dataset and Cleveland Dataset. For Pre-Processing of Datasets, The missing values were replaced with the Mean value and later 10 Fold Cross-Validation was utilized for the evaluation. The result of the performance analysis showed that SVM outperforms other algorithms against both datasets. SVM showed an accuracy of 84.156% against the Cleveland dataset and 84.074% against the Statlog dataset. LR showed a ROC Area of 0.9 against both datasets. The findings of the work will help Health Institutions to understand the importance and usage of Predictive Algorithms for the automatic prediction of CVD based on the symptoms.**

Keywords—Logistic regression (LR); support vector machine (SVM); Statlog; Cleveland; WEKA

I. Introduction

The heart is a vital organ that circulates rich oxygenated blood through coronary arteries. When these arteries block, such a situation is term as CVD. Major risk factors mostly relate to the patient's lifestyle (e.g., eating behaviour, obesity, smoking, alcohol, and physical inactivity). Global Burden of Disease (2019) reported that nearly a quarter of all deaths in India is because of CVD [1]. It is estimated that every year average of 17 million people dies from CVD, reported by World Health Organization (2019) [2]. There is another report in which the Lancet Medical Journal (2019) reported that women in India are more vulnerable than men [3]. Analyzing complex and similar EHRs is not a cost and effort effective solution.

Predictive algorithms in Data Mining have been used for finding patterns and generalize this for prediction in the last few decades. In our previous work [4], we have discussed: (1) The state-of-the-art for the usage of Data Mining in the Health Sector, (2) Top ten causes of Deaths from chronic Disease. One of the foremost applications of Data Mining in the Health Sector is to build an effective Clinical Disease Prediction System (CDPS) by the algorithm(s). Poorly designed CDPS can be devastating and may result in unwanted outcomes. But properly designed and analyzed CDPS will help hospitals to reduce their expenses. Traditional decision making in healthcare facilities is heavily reliant on the instincts and skills of doctors, rather than the amount of data concealed in EHRs. The consequences of this will be unintentional biases, mistakes, and superfluous medical costs that will impact patient care.

Before analyzing the algorithms, we had several questions like what algorithms to choose for CVD prediction, and on what basis. So, we put them as Research Questions (RQ) and later analyzed them on WEKA Tool. RQ for unbiased and effective analysis of algorithms are as follow:

- RQ1: What are the leading algorithms for the prediction of CVD after extensive study of related work?
- RQ2: Out of these, which Algorithm(s) outperforms other algorithms in terms of performance analysis?

This work divides into multiple Sections. Section II discusses related work by various researchers related to the prediction of CVD using data mining algorithms. Section III outlines the Methodology for performance analysis of the algorithms. This section briefly discusses the datasets, performance metrics, Software, and leading predictive algorithms. Section IV discusses the result of the analysis.

II. Related Work

To answer the RQ1, we have collected several research papers related to CVD from various sources such as IEEE Xplore, Google Scholar, Scopus, and Springer. Then these papers were filtered out based on the Year of Publication (2019—2021). This will help to find the recent usage of algorithms in the prediction of CVD. After extensive study, we have compiled the list of popular algorithms in Table I that answer the first research question. Further, these algorithms will use for performance analysis.

Muniasamy *et al.* [5] stressed on usage and applications of Machine Learning (ML) techniques for CVD prediction. They have used six algorithms viz. SVM, DT, k-NN, RF, and Linear Discriminant Analysis (LDA), Multilayer perceptron (MLP/ANN). They have used four heart datasets (i.e., Cleveland, Switzerland, Hungary, Long Beach VA) available on the UCI (University of California, Irvine) repository. They used 10-fold cross-validation for splitting training and testing data on WEKA software. Later their performance was evaluated using Metrics. Their work concluded that four algorithms i.e., LDA, RF, DT, and MLP suitable for the prediction of CVD.

Deshmukh et al. [6] suggested a Heart Disorder Prognosis System, in which they used two datasets from the UCI ML repository (i.e., Hungary, Cleveland dataset). They applied k-NN, ANN, DT, and SVM on described datasets using Python Programming language. Their result concluded that DT/ID3 outperform other algorithms on both datasets with the accuracy of 84.08% and 100%, respectively.

Garg et al. [7] performed a comparative analysis of five Data Mining Algorithms namely k-NN, NB, RF, SVM on four datasets collected from the UCI repository (i.e., Cleveland, Switzerland, Hungary, Long Beach VA). The analysis was performed using Python Programming language and concluded SVM outperforms others in terms of accuracy.

Katarya & Meena [8] used the python programming language to study the advantages and disadvantages of eight algorithms viz. LR, NB, SVM, k-NN, DT, RF, ANN/MLP, Deep Neural Network (DNN) for prediction of CVD.

Karun [9] performed a comparative analysis to find the best suitable model for the Prediction of CVD. They used the heart disease dataset from the UCI repository and concluded that RF outperforms other algorithms i.e., SVC/SVM, and k-NN.

Li et al. [10] proposed a feature selection algorithm i.e., “Fast Conditional Mutual Information (FCMIM)”. In their work, the Cleveland heart disease dataset was used, collected from the UCI repository. During pre-processing of data, data normalized by min-max scalar and then visualized using heat-map to understand the correlation. In the next phase, feature selection techniques viz. LASSO, MRMR, Relief, and FCMIM were applied to extract relevant features out of the dataset. To check the performance of each feature selection, data was passed to various classifiers (i.e., DT, ANN, LR, k-NN, SVM, and NB). Research work concluded that FCMIM when used with an SVM classifier gives better accuracy and reduces execution time than other cases.

Singh & Kumar [11] calculated the accuracy of various heart prediction algorithms such as SVM, k-NN, and Linear Regression classifiers. This work utilized the heart disease dataset from the UCI repository and then split it into 73% as a training dataset, 37% as a testing dataset. During the pre-processing phase, data balancing and feature selection were carried out on Jupyter (Python). Research work concluded that k-NN perform better than other classifiers in terms of accuracy (87%).

Choudhary & Narayan Singh [12] suggested using AdaBoost over DT because DT may lead to the over-fitting problem. They used the Cleveland dataset and experimented with the python programming language. Results concluded that AdaBoost gives almost the same accuracy (89%) at test sizes 40% and 10% of the model.

Sangle et al. [13] analyzed the theoretical aspect of different work in the field of ML and Deep Learning (DL) for the prediction of Cardiovascular Disease. They have studied the pros/cons of techniques like DT, k-NN, SVM, NB, ANN, and Ensemble Learning. Finally, the authors suggested using ensemble learning/hybrid models to boost the CVD model's prediction accuracy. Shah et al. [14] discussed and experimented with various predictive algorithms like NB, k-NN, DT, and RF where k-NN outperform other algorithms at k=7 in terms of accuracy. They have used the Cleveland dataset and analyzed it with Python Programming language.

Peng et al. [15] presented and discussed the importance/usage of ANN in the prediction of Cardiovascular disease. They have discussed previous work by various researchers related to neural networks for the prediction of CVD.

Hamdaoui et al. [16] proposed a clinical predictive system for Cardiovascular disease. They have used various algorithms like NB, k-NN, SVM, RF, and DT and then applied them to the Cleveland dataset. They used two separate validation techniques i.e., 10-Fold cross-validation, and 70-30 Split validation. In both, the scenario NB outperforms other algorithms. In Split validation, NB gets higher accuracy (84.28%) than Cross-Validation (82.17%).

Kumar et al. [17] calculated various performance metrics like Accuracy, AUC ROC score, and execution time of various classifiers such as RF, DT, LR, SVM, and k-NN. It utilizes a heart disease dataset from the UCI repository and was carried out on Jupyter (Python). Research work concluded that RF performs better in terms of accuracy (85%), ROC AUC score (0.8675), and execution time (1.09 sec).

Santhana Krishnan & Geetha [18] concluded that DT (accuracy=91%) perform better than NB (accuracy=87%) in terms of handling heart medical dataset. The experiment was carried out using Python Programming language by utilizing the heart disease dataset from the UCI repository.

Mohan et al. [19] presented a hybrid CVD prediction model based on RF with a Linear model. Feature selection was carried out using DT entropy and then the result passed to various classifiers like NB, Linear Model, LR, Deep Learning, DT, RF, Gradient Boost Trees, SVM, VOTE, and proposed model HRFLM. An experiment was carried out on R Studio and the result concluded that HRFLM produced better accuracy (88.47%) than other classifiers.

TABLE I. LIST OF ALGORITHMS WITH THEIR REFERENCE COUNT USED IN RELATED WORK

Algorithm	References	Count
SVM	[5], [6], [17], [19], [7]–[11], [13], [14], [16]	11
NB	[7], [8], [10], [11], [13], [14], [16], [18], [20]	9
DT	[5], [6], [18], [19], [8], [10]–[14], [16], [17]	12
k-NN	[5]–[10], [13], [14], [16], [17]	10
LR	[8], [10], [17], [19]	4
ANN	[5], [6], [8], [10], [13]–[15], [19], [20]	9
RF	[5], [7]–[9], [16], [17], [19]	7
Boosting	[12], [19]	2
LDA (others)	[5]	1

Repaka et al. [20] developed Smart heart Disease Prediction (SHDP) that collect heart-related data of the users and predict risk. AES (Advanced Encryption Standard) was used while storing the data, which helps in increasing data security. The research concluded that NB performs better than SMO (Sequential Minimal Optimization), Bayes Net, and MLP regarding accuracy and execution time.

III. Methodology

To answer the RQ2, This work purposed a methodology for finding which algorithm outperforms other algorithms in terms of performance. The complete and step-by-step workflow has shown in Fig. 1. This Section divides into four sections: (1) Datasets used and their pre-processing, (2) Algorithms selected from the first research question, (3) Software used for analysis, (4) Performance metrics.

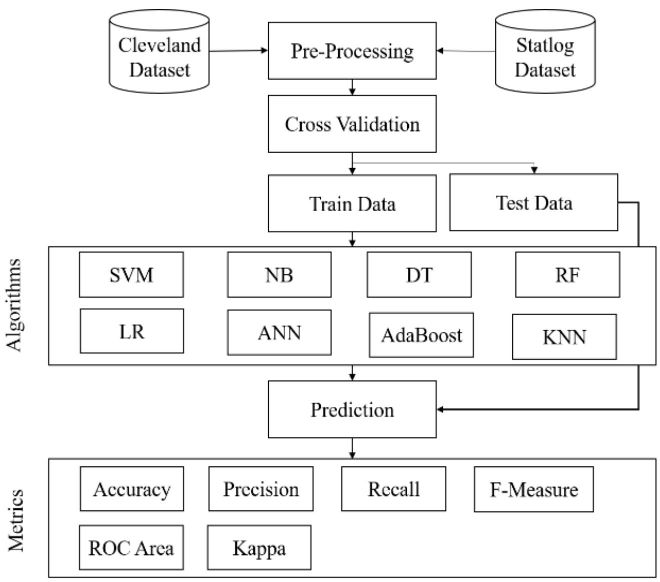

Fig. 1. Methodology for CVD Prediction.

A. Datasets

We have used two similar structured datasets related to CVD (i.e., Cleveland Dataset, Statlog Dataset). Both of these were collected from UCI ML Repository [21][22] and their properties in mentioned in Table II. Cleveland dataset contains 76 attributes, but only 14 attributes are usable for CVD prediction. In this dataset Age, Tresbps, Chol, Thalach, Oldpeak, and Ca are of numeric type and others are of Nominal type. Statlog dataset has 13 feature attributes. Unlike Cleveland dataset, it does not have any missing values. The goal of these datasets is to predict whether the patient is may suffer from CVD in the future or not based on feature attributes. If the outcome of the target variable comes Yes then it means the presence of Cardiac disease else not.

TABLE II. Properties of Datasets

Properties	**Cleveland Dataset**	**Statlog Dataset**
Number of Attributes	14	14
Number of Instances	303	270
Missing Values	Yes	No

B. Selected Algorithms

The selection of algorithm(s) largely depends on the Dataset and type of problem (e.g., classification, clustering etc.). Table I shows the list of popular algorithms after the extensive study (RQ1). In this sub-section, algorithms that had $Research\ Count \geq 2$ in Table I is discussed.

1) Support vector machine: SVM identifies the hyperplane with the greatest distance between two classes (see Fig. 2) [23]. The supporting vectors are the vectors (cases) forming the hyperplane. Researchers/Scholars must optimize the distance between hyperplanes. SVM employs a non-linear kernel function to map information at a place where a linear hyperplane cannot isolate the data. The kernel trick is the kernel function, which converts the data into a higher dimensionality, allowing for linear separation. In this work, we have used SMO (Sequential Minimal Optimization) function in the WEKA tool.

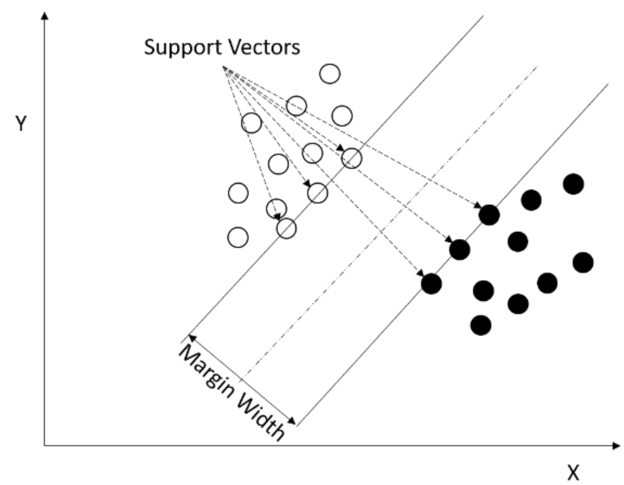

Fig. 2. Linear Support Vector Machine's Architecture.

2) Naïve Bayes: The foundation of the NB classifier is grounded on the theorem of Bayes (see Equation (1)) with the assumptions of independence among predictors [24]. An iterative parameter estimate that is especially useful for the very largest datasets is simple to construct, without a complicated iteration model. NB classifier does not struggle to be very simple and often works extremely well, as it often beats more complex classification methods. Here, we have used the NaiveBayes filter in the WEKA tool.

$$P(K|L) = \frac{P(L|K) \times P(K)}{P(L)} \quad (1)$$

Where $P(K|L)$ is the possibility of occurrence of K if L has already happened; $P(L|K)$ is the possibility of occurrence of L if K has already happened; $P(K)$, $P(L)$ is the independent possibility of event K and L respectively.

3) Decision tree: DT builds a prediction model in the shape of a tree structure [25]. DT provides a simple graphical solution to the problem which makes it most easily understandable among all classifiers. DT divides a dataset into successively smaller subgroups while building a new decision tree. The end output is a tree with decision/prediction and leaf nodes. The decision node has two or more branches (for example obesity? exercise?). A classified node (e.g., Unfit, Fit) is a decision as shown in Fig. 3. If Age < 40 and the person is Obese then it means the Patient is Unfit. If Age > 40 and not doing Exercise then the patient is unfit. DT is capable of handling both numerical and nominal/categorical attribute types. We have used the J48 (Implementation of DT based on JAVA) function in WEKA Tool.

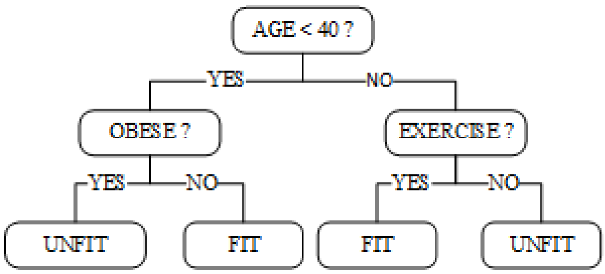

Fig. 3. Decision Tree for Obesity.

4) Random forest: RF (i.e., Random Forest) is a classifier that advances from DTs as shown in Fig. 4 and it consists of many decision trees [26]. Each decision tree provides training data as input and then their result aggregates and most voted will result as a prediction. Overfitting is a common concern in DT; RF aids in preventing this problem. Here, we have used the RandomForest function in WEKA Tool.

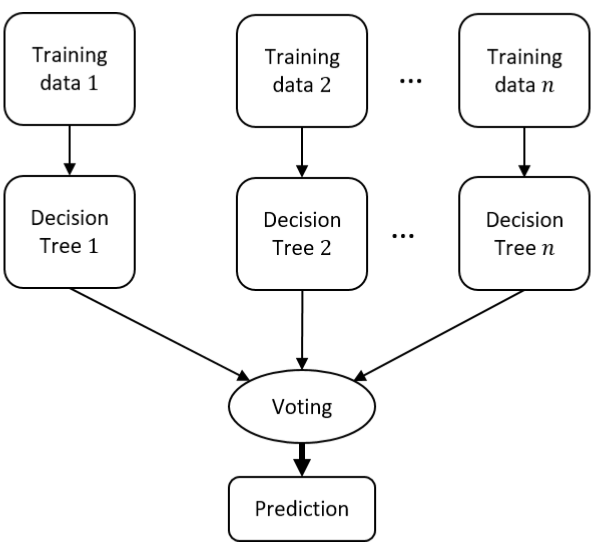

Fig. 4. Random Forest Tree Architecture.

5) Artificial neural network: ANN is composed of three layers: input, output, and hidden layer(s) as shown in Fig. 5 [27]. The input layer nodes communicate with the hidden layer nodes, as do the output layer nodes from each hidden layer node. The network data are taken from the layer of input. The hidden layer receives raw data from the input layer and processes it. The value obtained is transferred to the output layer, which also processes and returns data from the hidden layer. Incapable of justifying its choices is ANN's most critical shortcoming. Here, we have used the MutilayerPerceptron function in WEKA Tool.

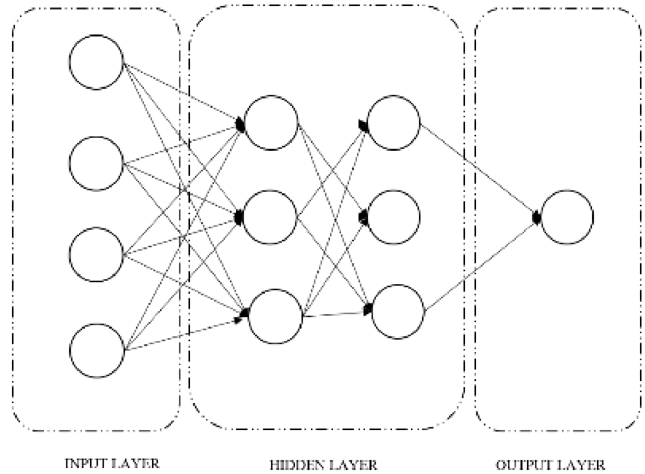

Fig. 5. Simple ANN Architecture.

6) Logistic regression: LR uses sigmoid function instead of linear function as shown in Fig. 6 [28]. In Fig. 6, y represents linear regression and probability p represents LR. The vertical axis is the likelihood of a particular number, and the horizontal axis represents the value of x. A sigmoid function is used by the logistic function to limit the y value from a wide-scale to inside the range (0, 1). Here, we have used the SimpleLogistics function in WEKA Tool.

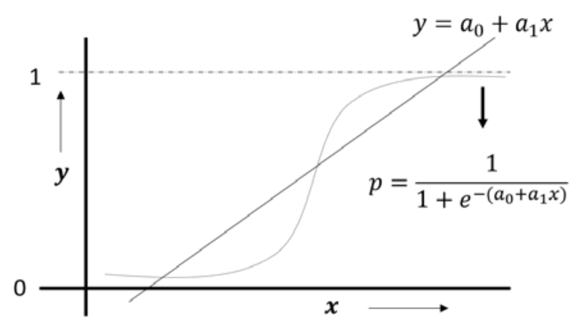

Fig. 6. Graphical Comparison of LR and Linear Regression.

7) Adaptive boosting: Adaptive Boosting (AdaBoost) is an ensemble learning technique that is used to enhance the accuracy of weak binary classifiers i.e., DT. Unlike RF, here weak classifiers add sequentially. For Dataset having number N feature variables, N decision stumps will create. Initially, all decision stumps assigned equal-weighted data. The selection of the base model (first stump) will be based on the lesser value of Entropy. After that, each observation updates with normalized new weight based on performance and total error. Finally, based on a random number and normalized weight a new decision stump will select, and so on. In WEKA Tool, Implementation of Adaptive Boosting is known by AdaBoostM1.

8) k-Nearest Neighbors: k-NN is a classifier that classifies data points based on their closest neighbours. Implementation of k-NN consists of simple steps. Initially, data points transform into vectors. In the next step, the distance between vector points is found by using a mathematical equation such as Euclidian Equation, and Manhattan distance shown in Equation (2). Then the probability of these points calculates being like test data. Finally, the classification of these vector points having the highest probability. Here we have used the IBk (Instance-Based Learner) (Implementation of k-NN) function in WEKA Tool.

$$d(p,q) = \sum_{i=1}^{t} |p_i - q_i| \qquad (2)$$

where $d(p,q)$ is the distance between vector p and q; t denotes the number of data points in the vector.

C. Software used

WEKA (Waikato Environment for Knowledge Analysis) is a free and open-source software application designed to address a range of data mining issues [29]. The framework allows the implementation of several algorithms for data analysis and provides an API to call inbuilt algorithms from a particular application by JAVA Programming Language. It provides a variety of tools for classification, regression, clustering, removes irrelevant features, builds associate rules, and visualization of the dataset. We have used WEKA v3.8.5 on Intel® Core™ i3 @ 1.70GHz with 8GB RAM on x64 bit Windows 10 Operating System.

D. Performance Metrics used

1) Confusion matrix: Confusion Matrix represented by $N \times N$ table shown in Fig. 7 that describes how well a classifier performs for which the true values are known. It consists of 4 entities. True positive (TP) are the cases where the classifier predicted that patients have the illness and, they have the illness. True negatives (TN) are those where classifier predicted patient does not have the illness and, they have no illness. False-positive (FP) is also referred to as Type I Error. In this, the classifier predicted that patients have the illness but, they do not have. False-negative (FN) is also referred to as Type II Error. In this case, the Classifier anticipated that the patient would not have the disease, but they do.

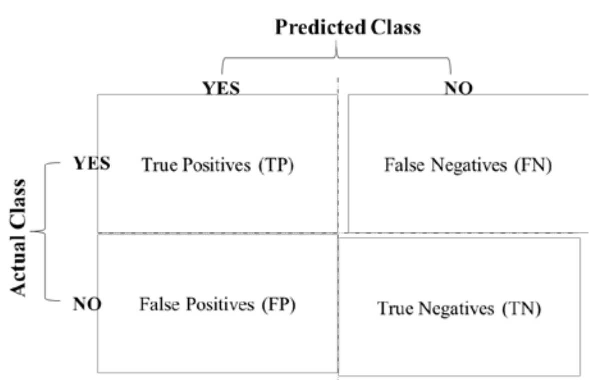

Fig. 7. Representation of Confusion Matrix.

The confusion matrix will then be used to determine Accuracy, Precision, Recall (Sensitivity), and F-Measure. Accuracy means how often is the model correct? Mathematically, it is shown in Equation (3). Precision is defined as the ratio of True Positives to Total Positives and the recall is how many true positives were found by the model. Mathematically, Precision and Recall are shown in Equation (4), Equation (5), respectively.

F-Measure is defined as the Harmonic Mean of Precision and Recall as stated in Equation (6). Instead of balancing the trade-off between Precision and Recall, the researchers can look for a good score of F-Measure. The Receiver Operator Characteristic (ROC) curve is a probability curve that compares the True Positive Rate (TPR) to the False Positive Rate (FPR) at different threshold levels. The greater the ROC Area, the better is the model's ability to differentiate between positive and negative groups.

$$Accuracy = \frac{(TP+TN)}{(TP+FP+FN+TN)} \qquad (3)$$

$$Precision = \frac{(TP)}{(TP+FP)} \qquad (4)$$

$$Recall = \frac{(TP)}{(TP+FN)} \qquad (5)$$

$$F\ Measure = 2 \times \frac{precision \times recall}{precision + recall} \qquad (6)$$

2) Cohen's kappa: These metrics use to measure how closely the instances are classified by the classifier when matched with labelled data as ground truth. It is mathematically shown in Equation (7). The greater the value of Cohen's kappa, the greater will be the level of agreement and the higher will be the percentage of reliable data. A value below 0.60 usually considers a weak classifier.

$$Cohen's\ kappa = \frac{P_a - Pe}{100 - P_e} \qquad (7)$$

where P_o is actual percentage agreement, P_e is expected percentage agreement based only on chance.

IV. Experimental Results

This paper examined two research questions for effective and unbiased analyzing the algorithms. To answer RQ1, we have inspected the extensive state-of-the-art related to Predictive algorithms and CVD. Table I clearly showed that *SVM, NB, DT, RF, LR, ANN, AdaBoost and k-NN* are the most common and popular choices for CVD prediction. To answer RQ2, we stated methodology for opting which algorithm outperforms on two similar structured datasets (i.e., Cleveland Dataset and Statlog Dataset). Unlike the Statlog dataset, Cleveland Dataset poses missing values. To remove these missing values, we have applied ReplaceMissingValues Filter in WEKA that replaced these values with modes/means. Later balancing of Datasets has performed by ClassBalancer filter so that each class has the same total weight.

Following data pre-processing, each dataset was divided into Training and Testing data (for validation) using 10-fold cross-validation. Algorithms from RQ1 were applied to these datasets. To measure the effectiveness of these algorithms, each one was put to the test using performance measures, the results of which were displayed in Table III and Table IV.

Against Cleveland Dataset, the result of the performance analysis showed that both SVM and ANN perform better than other selected algorithms with the accuracy of ~84.15% and ~84.09% respectively (Table III). DT scored 73.62%, Naïve Bayes scored ~81.67%, RF scored ~81.37%, Logistic Regression scored ~81.37%, AdaBoost scored ~82.99%, and k-NN scored ~75.74% in terms of accuracy. The accuracy of the ANN classifier is very close to SVM but the ROC Area value of ANN (0.907) is more than SVM (0.842) (see Table III). So, both ANN and SVM are suitable choices for the prediction of CVD against the Cleveland Dataset.

Analysis Result against Statlog Dataset showed there were three algorithms whose performance was worthy to talk about (Table IV). SVM scored the highest accuracy of ~84.07%. Next in order, NB and LR showed the same accuracy of ~83.70%. DT scored ~76.66%, RF scored ~76.29%, ANN scored ~78.14%, AdaBoost scored 80% and k-NN scored ~75.18% in terms of accuracy. If we compare the ROC area then both NB and LR are better than SVM (see Table IV).

The results discussed were about individual datasets. If we compared the accuracy of algorithms against the Cleveland dataset and Statlog dataset then SVM performed better than other algorithms (see Fig. 8). Against Cleveland Dataset, it showed an accuracy of ~84.15% and Against Statlog Dataset, it showed an accuracy of ~84.07%. Next in order, NB showed an accuracy of ~81.67% against the Cleveland Dataset and an accuracy of ~83.70% against the Statlog Dataset.

TABLE III. PERFORMANCE METRICS OF THE ALGORITHMS AGAINST CLEVELAND DATASET

Algorithms	Accuracy (in %)	Precision	Recall	F1	ROC Area	Kappa
SVM	**84.1568**	0.843	0.842	0.841	**0.842**	0.6831
NB	81.6733	0.817	0.817	0.817	0.899	0.6335
DT	73.6232	0.736	0.736	0.736	0.741	0.4725
RF	81.3702	0.814	0.814	0.814	0.900	0.6274
LR	81.3702	0.814	0.814	0.814	0.900	0.6274
ANN	**84.0909**	0.841	0.841	0.841	**0.907**	0.6818
AdaBoost	82.9974	0.830	0.830	0.830	0.892	0.6599
k-NN	75.7444	0.758	0.757	0.757	0.750	0.5149

TABLE IV. PERFORMANCE METRICS OF THE ALGORITHMS AGAINST STATLOG DATASET

Algorithms	Accuracy (in %)	Precision	Recall	F1	ROC Area	Kappa
SVM	**84.0741**	0.841	0.841	0.840	**0.785**	0.6762
NB	**83.7037**	0.837	0.837	0.837	**0.898**	0.6683
DT	76.6667	0.766	0.767	0.767	0.744	0.5271
RF	76.2963	0.764	0.763	0.763	0.762	0.5216
LR	**83.7037**	0.837	0.837	0.837	**0.900**	0.6683
ANN	78.1481	0.784	0.781	0.782	0.839	0.5601
AdaBoost	80.0000	0.800	0.800	0.800	0.878	0.595
k-NN	75.1852	0.753	0.752	0.752	0.750	0.4988

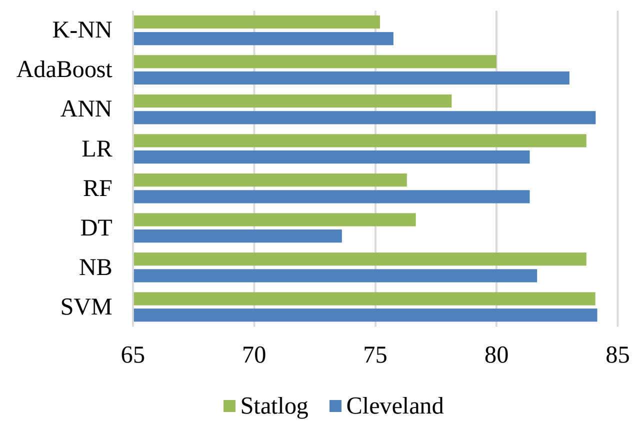

Fig. 8. Comparison of Accuracy (in %) against Cleveland and Statlog Dataset.

Algorithms having a ROC Area value near 1 generally consider a good classifier against the dataset. LR scored a ROC Area of 0.9 against both datasets (see Fig. 9). Next in order, ANN showed 0.907 against Cleveland Dataset and 0.839 against the Statlog Dataset.

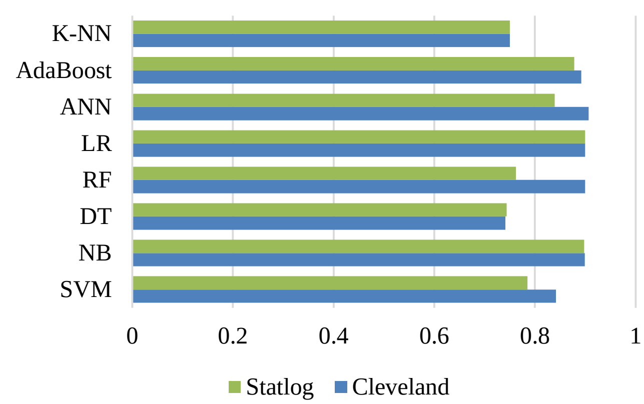

Fig. 9. Comparison of ROC Area against Cleveland and Statlog Dataset

V. CONCLUSION AND FUTURE WORK

Predictive Algorithms founds to be very effective in the automatic prediction of CVD. In this work, we analyzed popular predictive algorithms namely SVM, NB, DT, RF, LR, ANN, AdaBoost and k-NN. They were chosen based on the state-of-the-art related to the CVD and Predictive Algorithms. The experiment was conducted using two similar structured datasets (i.e., Cleveland and Statlog Dataset) on open-source WEKA software. The outcome of the experiment concluded that (1) SVM showed maximum accuracy against the datasets, (2) LR showed a ROC Area of 0.9 against both the datasets. These results imply that (1) SVM shows better accuracy against most of the datasets by finding optimal hyperplane using kernel tricks, (2) LR shows better ROC Area against the binary classification datasets.

These findings will help the researchers and Health institutions (1) To understand the current trends related to CVD prediction using the algorithm(s), (2) To build successful and effective CDPS (i.e., Clinical Disease Prediction System) for CVD. Unfortunately, we were unable to study and analyze hybrid models/algorithms but it can extend in future by considering this work as a blueprint/base. Future work should give priority to (1) Real-time and Complexed CVD data, (2) Ensemble Learning and Hybrid Models for analysis, (3) Checking the effects on the value of Performance Metrics against different validation and features selection techniques.

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Enhanced Clustering-based MOOC Recommendations using LinkedIn Profiles (MR-LI)

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***Abstract*—With the rapid development of massive open online courses (MOOCs), the interest of learners in MOOCs has increased significantly. MOOC platforms offer thousands of varied courses with many options. These options make it difficult for learners to choose courses that suit their needs and compatible with their interests. So, they become exposed to many courses on all topics. Therefore, there is an urgent need for personalized recommendation systems that assist learners in filtering courses according to their interests. Therefore, in this research, we target learners on the professional platform, LinkedIn, to be the basis for user modeling; the number of extracted profiles equals 5,039. Then, skill-based clustering algorithms were applied to LinkedIn users. Subsequently, we applied the similarity measurement between the vector features of the resulting clusters and the extracted course vectors. In the experiment result, four clusters were provided with the top-N course recommendations. Ultimately, the proposed approach was evaluated, and the F1-score of the approach was .81.**

Keywords—MOOCs; recommendation systems; content-based; clustering; term frequency-inverse document frequency (TF-IDF); LinkedIn

I. Introduction

Currently, the world has significantly developed regarding the services provided to learners over the internet. These services have expanded to include courses, academic qualifications, and science lessons and have become known as e-learning. After the emergence of e-learning, many students worldwide have participated in online courses in virtual classes [1]. Recently, E-learning has gained colossal attention since the emergence of Massive Open Online Courses (MOOCs), which attract numerous learners to engage[2]. MOOCs are an online platform that provides services for learners of different ages and academic levels worldwide in different geographic locations. It serves the community's largest possible segment and has more than 100 million students [3]. Some MOOCs are offered as free educational courses for learners in various fields in many languages. It is also characterized by its flexibility to accept students and facilitate their access to available educational content. MOOCs offer different styles to deliver courses where they can access course content in text or video lectures. They can take advantage of extending course content by using discussion boards or blogs [4][5]. MOOC evolutions are considered the most popular platforms that have evolved to include all countries globally, with many providers such as Coursera, Udacity, Udemy, and Edx [6].

However, due to the large number of provided courses, the learners may face difficulties obtaining the desired content. In terms of choosing the right course, the number of users who make a wrong decision exceeded 90% [7]; thus, a meaningful recommendations engine has become critical for MOOC users. Based on these facts, the importance of personalized recommendations for users in education or other fields should be mentioned. The recommendations provided to learners have great significance and may be one of the most critical factors motivating them to expand their learning experience with various courses offered to them. MOOC recommendations have importance for both sides, learners, and MOOC providers, as learners face difficulty reaching the appropriate content. At the same time, MOOC providers also face problems represented in suggesting the proper course. There are different recommendation techniques; some recommendations can be achieved using collaborative filtering methods, which provide the learner with recommendations similar to the courses that their peers joined in the platform. Other systems have relied on user modeling by analyzing their search history in the platform or analyzing their profile in the MOOC platform [8]. Recent studies have confirmed that the most effective methods in the recommendations are the ones that rely on the analysis of social networks because it is closer to match the taste of users. Recommendation systems used social network data to give the user more customized recommendations based on each user's personal information [9]. This research has relied on the utilization of social network content to customize recommendations. Specifically, LinkedIn was chosen to be the primary source for this research's dataset for many reasons. First, it is one of the best professional social networks where users express their education, academic experience, skills, and educational interests. The proposed approach in this paper analyzes users' profiles on LinkedIn and then provides course recommendations for the most appropriate course of these profiles.

The paper will be organized as follows: Section 2 will discuss the related works to MOOC recommendation systems, especially content-based systems. Then, Section 3 will discuss our proposed approach to courses recommendation based on LinkedIn data, starting with data collection, description, cleaning, the clustering process for LinkedIn profiles, and the recommendation process. Then, the evaluation process of the proposed approach will be discussed in Section 4. After that, we will discuss the results in Section 5. Finally, in Section 6, we will conclude the work and present the future directions for this research.

II. Literature Review

Due to the knowledge and information rapid explosion worldwide, there is an urgent need to improve the efficiency of the learning process. Therefore, MOOC platforms became more popularized to fulfill this need equipped with recommendation systems.

Recent studies have also confirmed the effectiveness of integrating information derived from social networks with recommendation systems in terms of accuracy. The additional information about the user increases the understanding of the user's behavior and preferences. Thus, the user can be better understood and modeled, reflecting positively on the accuracy of the recommendation [8][10]. Data mining has helped researchers develop recommendation systems (RSs) to provide users with suggestions related to specific items or content to achieve personalization [11]. Many studies were initiated to assist in recommend courses for learners. For example, Dumitru Radoiu [7] addressed the user attributes, user behaviors, and item attributes in MOOC platforms such as 'user profile' (user attribute), 'user history' (user behavior), and 'course description' (item attribute) to provide learners with suitable course recommendations to improve their completion rate.

Other ways to use recommendation systems in e-learning, as in the study by Kardan et al. [2], which analyzed social networks to lead learners to match relevant information in MOOC platforms. Additionally, in terms of the efforts to solve the cold start problem, a study by Kumar Abhinav et al. [12] presented a framework of hybrid recommendation systems. Many predictive models have been used to contribute to providing efficient course recommendations for learners. At the same time, other studies such as Xiao Li et al. [13] have applied the user preferences and behavior inside the demographics data to develop accurate recommendations to serve their needs. The definitive study by Alzahrani & Maccawy [14] proposed a hybrid model for MOOC search based on personalization known as the MOOC Recommender Search Engine (MRSE) to access relevant courses easily. In a new study in 2021, Khalid et al. [15] proposed an algorithm based on ratings. The system implements a new algorithm characterized by flexibility and scalability; what is more, it is more accurate than previous algorithms. Its results were also compared with the Collaborative Filtering and Clustering algorithms, and they showed great superiority in the accuracy and classification metrics.

Furthermore, in content-based recommendations algorithms, the item's content is used to provide recommendations; it includes the information to describes the items [11]. Many studies have adopted this technique in building MOOC course recommendation models for learners. For example, a study by Piao & Breslin [16] presented a system that gives learners personalized recommendations by taking advantage of their LinkedIn pages' data. This system ranks the courses obtained from Coursera (using google custom search engine GCSE) according to its similarity with the user's profiles. Jing & Tang [17] developed a new algorithm called Hybrid Content-Aware Course Recommendation (HCACR); they employ collaborative filtering to develop a course recommendation algorithm that combines user interests and demographics as well as analyzes pre-course requirements. They tested the proposed algorithm on the "XuetangX" platform [18], a Chinese courses platform; their algorithm proved its effectiveness, as it achieved a high click rate on the recommended courses. Another study by Huang & Lu [19] presents a content-based MOOC model for intelligent education, contributing to user profiling development. They have used user interest analysis on the MOOC page to create a user profile and provide recommendations that match the user's activity log. In another study by Zhang et al. [20], the authors developed a recommendation model based on content analysis for learners and educational courses (named MOOCRC), which relies on deep belief networks (DBNs). This graphical model combines probability and statistics with machine learning and neural networks in MOOC environments. Their proposed model achieved higher accuracy and coverage rate than the traditional recommendation systems. Using a context-aware factorization machine algorithm, Chanaa & El Faddouli [21] designed a new recommendation approach for a MOOC platform in order to provide further recommendations that aligned with each learner using predictions about user behavior; this was studied by analyzing user interactions in the MOOC platforms, including rating, feedback, and likes.

In specific applications, many researchers used LinkedIn in recommending MOOC courses. LinkedIn offers the opportunity to obtain the user's profile in order to analyze the user's educational taste. Users' profiles contain reliable information about learners' scientific backgrounds and research fields, which is considered the largest professional social network on the internet [22]. Besides the valuable information existing in user profiles, such as the educational degree and work experience [23]. In a similar study of Dai et al. [24], the data was collected and analyzed from the professional profiles on LinkedIn. The authors used the natural language processing techniques (NLP) to study the users' behavior on Online Social Networks (OSN) to provide recommendations that improve their decision-making process. Also, Dai et al. [25] used the available personal data on LinkedIn pages to provide customized recommendations to learners based on their preferences. However, these preferences were built by focusing on the job market to make the recommendations more relevant to the job market's needs. Another study for Pourheidari et al. [9] used data taken from two well-known social networking sites, LinkedIn and Twitter, to provide users with recommendations that essentially correspond to their information written on LinkedIn and Twitter. This study proved to be highly effective in recommendation systems. The last research was by Kumalasari and Susanto [26], who collected data from professional profiles on IT professionals from LinkedIn to be used as a reference for the skills presented later as a recommendation for students (job seekers).

A. Research Gap

The learners had difficulty in obtaining the appropriate training courses. There have been many studies to solve this problem, and one of the most effective ways is to provide personalized recommendations for learners. Therefore, this research will present a personalized recommendations approach for learners based on their skills. According to the literature, the studies that used the content-based recommendation had a good performance. Other studies that used social networks in personalization also achieved recommendations closer to the learner's needs. Therefore, in this research, these two features will be combined to personalize courses for learners better.

The content-based recommendation will be used as well as the applying of clustering algorithms besides utilizing the TF-IDF technique. Recommendations will also be personalized based on social networks. Therefore, in this research, the professional social network "LinkedIn" will be relied upon, as it is the most formal social network; besides focusing on the user's skills present on LinkedIn. In addition, the studies that highlight users' skills in LinkedIn are limited, so the skills here will be used as a guide to the course's recommendation process since it was closest to describing the user's interest. So, the contribution of this research will be to apply clustering algorithms to LinkedIn users to provide personalized course recommendations to learners based on their profiles, especially their skills present on LinkedIn.

III. MOOC Recommendation based on LinkedIn Profiles KR-LI Approach

A. Proposed Approach

This section presents our approach "MOOCs Recommendation based on LinkedIn MR-LI" to recommend MOOC courses to learners based on their LinkedIn profiles. This approach aims to identify the learner's interests through the mentioned skills in him/her profile that explicitly expresses the scientific field in which he/she is interested. Fig. 1 illustrates the general framework for the proposed approach.

First, the approach extracts data from the LinkedIn and Coursera websites. The crawling process is performed on LinkedIn profiles to scrape the entire information from each profile, and then store the scrapped data into a user's dataset. As well as for Coursera, then it is stored in a separate dataset for the courses. Second, the approach begins with the cleaning and preprocessing of datasets. Third: LinkedIn users are clustered into clusters based on the similarities between the users. At this step, the skills field on LinkedIn is taken as a feature for clustering on its basis. Fourth: begins with the feature extraction for datasets (LinkedIn and Coursera) and the calculation of weights for feature vector construction using term frequency-inverse document frequency TF-IDF. Fifth, the similarity between the learners and the courses is measured using Cosine Similarity. Finally, the approach provides recommendations for learners' clusters with ten courses that are most similar to these clusters. The following section will discuss these steps in detail.

B. Dataset Collection

1) LinkedIn dataset: In order to validate MR-LI, we used LinkedIn as the primary resource for our learners' dataset. This is because LinkedIn is one of the most popular social network sites in which people express their interests and educational backgrounds more formally and professionally, as it is specific to employment and education development, so it is the best environment to obtain accurate data for the recommendation process [9].

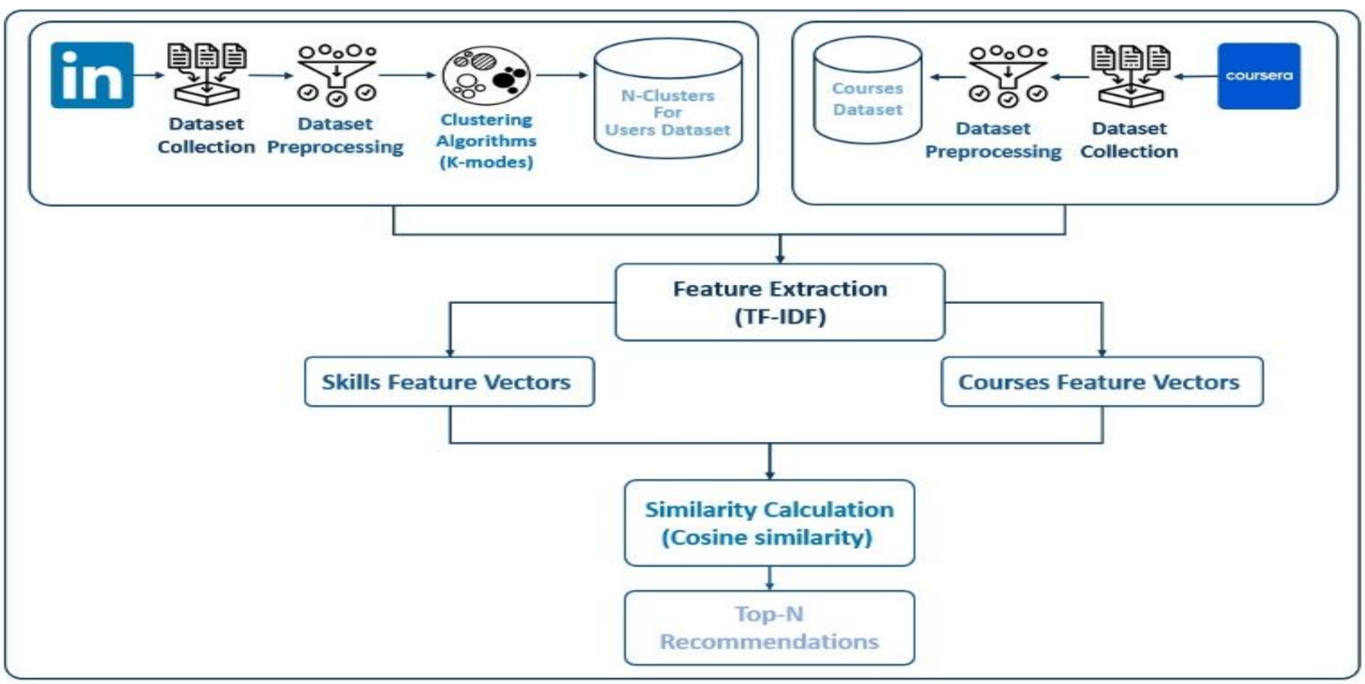

Fig. 1. The Framework for the Proposed Approach MR-LI.

We used Python as the programming language to deal with the LinkedIn API. The BeautifulSoup and Selenium libraries were used to access users' profiles [24] and then store the data in JSON and CSV format. Using LinkedIn API, we can access public data for users such as name, current job, past jobs, degrees, brief description, skills, interests, languages, etc. Fig. 2 provides an example of a public profile on LinkedIn. There are two profile types on LinkedIn (public & private), and we can access the public profile only. In order to extract our dataset, we identified the subscribers in common companies and universities in Saudi Arabia to reach the actual active users in Saudi Arabia. After the data scrapping process, the number of users reached more than 20,000. Table I shows the most important information on users' LinkedIn profiles.

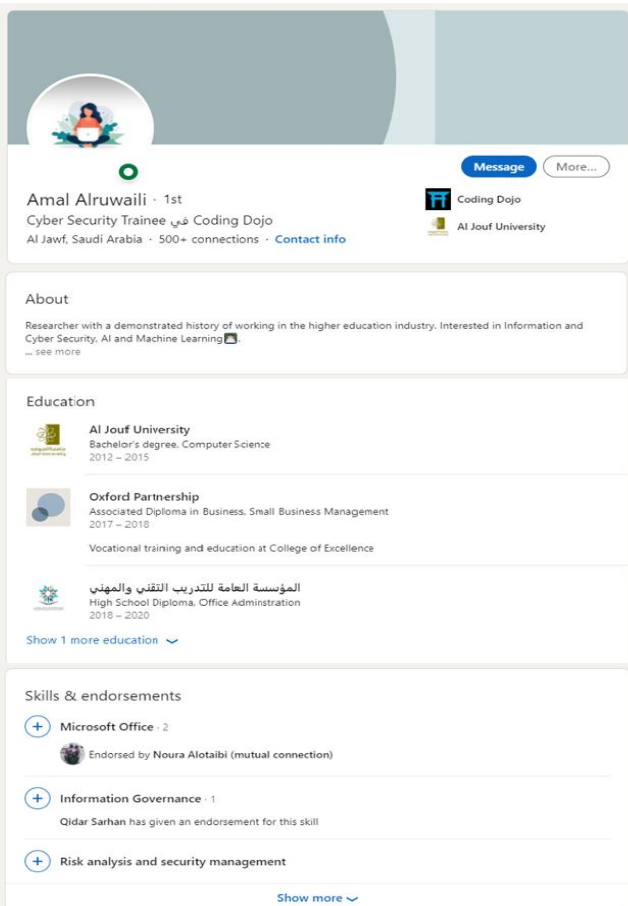

Fig. 2. Example of Full Profile on LinkedIn.

TABLE I. THE MOST IMPORTANT INFORMATION ON USERS' LINKEDIN PROFILE

Field Name	Description
About	Brief introduction about the user.
Activity	Posts the user publishes and the posts he/she interacts with.
Experience	Practical user experiences.
Education	Educational qualifications obtained by the user.
Licenses & Certification	Professional licenses and certificates are obtained by the user.
Skills	Skills the user possesses.

2) Coursera dataset: Conversely, to obtain data for the courses that will be recommended to learners, we have chosen the Coursera website [27], one of the largest global platforms that offer courses in various technology fields and others. Coursera provides details about the courses on each course page, as in Fig. 3. Therefore, it is considered an excellent platform in terms of the details available about the offered courses. The API with BeautifulSoup and Selenium libraries on Python also have been used to scrape 12173 courses in JSON and CSV format. Table II shows the most important information on the course page on the Coursera website, such as the course title, description in "about this course", instructors, etc.

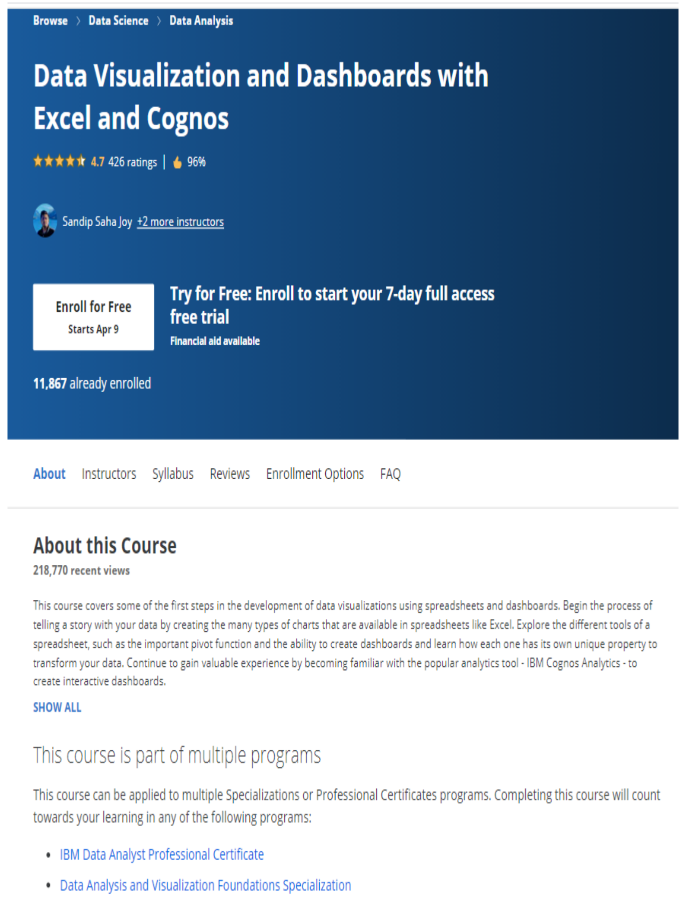

Fig. 3. Example of Course on Coursera.

TABLE II. THE MOST IMPORTANT INFORMATION ON THE COURSE PAGE

Field Name	Description
Course Title	Title of the course.
About	General description of the course and its contents.
Instructors	Details about the instructors presenting the course.
Syllabus	Details about the course content.
Review	Learners' rating and feedback about the course.
Enrolment Options	Options for attendance and payment methods.

C. Dataset Cleaning and Preprocessing

1) LinkedIn dataset: The initial total of data extracted was over 20,000 files. In order to obtain satisfactory results, files that do not contain primary data for the recommendation process include: profileurl, firstname, lastname, schooldegree, schooldegreespec, schooldegree2, schooldegreespec2, allskills, skill1, skill2, skill3, skill4, skill5, and skill6 are excluded. Also, the number of profiles written in Arabic was scarce due to the reliance of the majority of users on writing their profiles in English. Because the small dataset number did not yield satisfactory results, we had to exclude the Arabic profiles. Therefore, emphasis was placed on the English profiles only; the profiles written in other languages were excluded.

In addition, we performed some preprocessing on the data: first, transforming the text to lowercase. Second, removing the punctuations, stop words, and URLs. Third, excluding meaningless rows with long descriptions from skills or not writing them in text. Fourth, excluding profiles that contain less than six skills. Finally, separating the skills using "|". The data size after cleaning amounted to 5,039 files.

LinkedIn gives its users complete freedom to express themselves, their skills, academic qualifications, and experiences [24]. Therefore, there is no specific way to write the skills. For example, we find that a person may express 'Leadership' in 'Team Leadership', 'Team Management', or 'TeamLeadership'. In this way, the writing style can affect the distribution of users in clusters. Therefore, we normalized the skills as shown in Table III. After that, we performed the lemmatization process on the dataset to avoid data duplication. By the end of this process, we found that the common skills were "Microsoft Office", "Project Management", "Teamwork", and "Leadership".

TABLE III. THE NORMALIZATION FOR LINKEDIN DATASET

Skill	Keywords
'Programming'	'Program', 'programming'
'Project Management'	'Project', 'Project management', 'PMP', 'End-to-End Project Management'
'Teamwork'	'Team', 'Team work', 'Team Work', 'team work'
'Leadership'	'Team Leadership', 'Team Management'
'Time Management'	'Time', 'Time Management', 'time management', and 'TimeManagement'.
'Accounting'	'Accounts', 'Accountant', and 'Accounting'.
'Microsoft Office'	'Office', 'Microsoft', and 'microsoft'.
'Presentation Skills'	'presentation', 'presentation skills'.
'Strategic Planning'	'Strategy', 'Strategic',
'Data Analysis'	'Data', 'Data Analytics',
'Financial Analysis'	'finance', 'Finance', 'Financial'
'Web Development'	'Web', 'webdenepment', 'webdeveloper'.
'Business Development'	'Business', 'Business developer', 'Business Skills'.
'Quality Assurance'	'Test', 'Tester', 'Quality', 'Assurance of quality'.
'Object-Oriented Programming (OOP)'	'OOP', 'Object-Oriented Programming'

2) Coursera dataset: The scraped data contains the following information: CourseId, Description, CourseTitle, DurationInSeconds, ReleaseDate, AssessmentStatus, IsCourseRetired. However, the primary data for each course is the CourseId, CourseTitle, and Description columns, so courses that do not contain this information have been excluded. Also, the "IsCourseRetired" column represents the course's state in real-time is available or not. So, the courses with value = "No" in this column were excluded from the recommendation process to avoid making recommendations to learners with unavailable courses. The data have been cleaned of stop words, symbols, punctuation marks, and all characters except numbers and letters. Also, terms like "ll" used in "Description" texts, such as 'we'll' and 'you'll', were also removed along with '-' (hyphens) from the CourseId. The data size after the cleaning equaled 3,471 courses.

D. Clustering LinkedIn Profiles

The purpose of this section is to categorize users based on their skills. Nevertheless, due to the freedom granted to users by LinkedIn, they can express their skills in various names without using pre-defined labeling. So, LinkedIn profile fields do not follow a specific standard, such as the UNESCO used to classify the users' skills [28]. In this sense, the classification algorithms become very difficult. So, the solution here is clustering algorithms, as it clusters the users according to how similar they are to each other. Considering the size of the obtained dataset, we decide to apply the K-modes clustering method due to its efficiency and effectiveness in the used size of the dataset. Before using the K-modes algorithm, we must determine the number of clusters "k" since it is a sensitive parameter for this clustering process [24]. We applied the Elbow method to guide the choice of the "k" parameter [29].

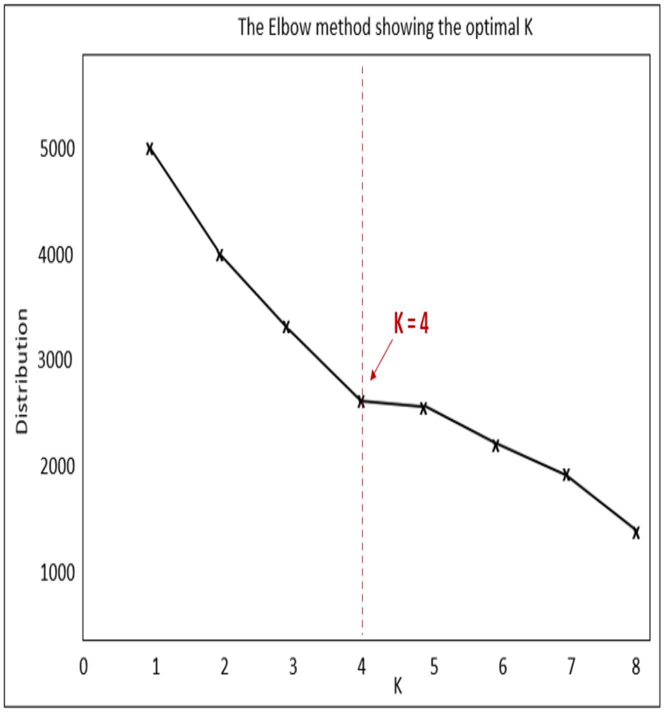

Fig. 4. The Result of the Elbow Method.

As shown in Fig. 4, the elbow method computes the squared distance's total for each cluster. We assign different k-values from 0 to 49; by analyzing the generated graph, it is clear that the k equals the breakpoint, which is the elbow point. In this case, according to the graph, the optimal k will be 4.

The K-Mode algorithm was applied to 5039 profiles. Table IV shows the number of profiles in each one of the four clusters.

We notice that more than 75% of the profiles are located in the first cluster. Therefore, a lemmatization process was performed on the dataset to reduce the similarity between profiles. Table V represents the distribution of the profiles on the four clusters after the lemmatization process.

We created word clouds corresponding to each cluster to clarify the distribution of the profiles in the four clusters. In the beginning, we notice the repetition of some skills in all clusters, such as "Microsoft Office", "Teamwork", and "Time management", but at different rates from one clause to another. Table VI shows the commonly used skills in each cluster.

For the first cluster, as shown in Fig. 5, it is clear that the most common skills among users are combined, and this explains why it is the largest cluster among the four clusters, as it contains "business," "planning," "problem-solving," and "communication" as the most common skills in this cluster. As for the second cluster in Fig. 6, it is clear that the most common skills are "human resources", "development", "recruit", "team management", and "social media", it can be described as it combines social, employment, and communication skills in general. As for the third cluster in Fig. 7., it is widely noted that it combines skills that indicate interest in the field of cybersecurity such as "defense", "protection", "threat", "awareness" and "iam", which are terms widely used in the field of cybersecurity. Finally, the fourth cluster in Fig. 8 gathered skills that generally referred to project management and software engineering. Fig. 9 shows the skills that are most frequently used among the users of the four clusters.

TABLE IV. THE NUMBER OF PROFILES IN EACH CLUSTER

Cluster ID	Number of profiles
Cluster 1	3,859
Cluster 2	392
Cluster 3	367
Cluster 4	448

TABLE V. THE NUMBER OF PROFILES IN EACH CLUSTER AFTER THE LEMMATIZATION

Cluster ID	Number of profiles
Cluster 1	3,175
Cluster 2	463
Cluster 3	952
Cluster 4	448

TABLE VI. THE COMMONLY USED SKILLS IN EACH CLUSTER

Cluster ID	Common Skills	
Cluster 1	Microsoft excel server test software database leadership creative integration analytical	warehouse business quality databases android teamwork communication problemsolve selfconfidence *management
Cluster 2	teamwork Leadership hr management analysis change corporate relationship research strategic	plan recruit coach staff project data analysis quality performance documentation
Cluster 3	cybersecurity threat identity risk ld software access control iso disasterrecovery *	iam vulnerability assessment delay defense data protection regulation continuity authentication
Cluster 4	mysql application scalability requirement database design solution information technology startup	agile software lifecycle sdlc intelligence change test database integration scrum

Fig. 5. Wordcloud of Cluster 1.

Fig. 6. Wordcloud of Cluster 2.

Fig. 7. Wordcloud of Cluster 3.

Fig. 8. Wordcloud of Cluster 4.

E. Recommendation Process

This phase consists of two steps in which we aim to identify the recommended courses for the four user clusters.

1) TF-IDF: In order to extract the important features in the datasets, the term frequency-inverse document frequency (TF-IDF) was used, which proved to be effective in detecting important words for the dataset [30]. In the vector space model, TF-IDF is the commonly used weighting method in describing the documents [31].

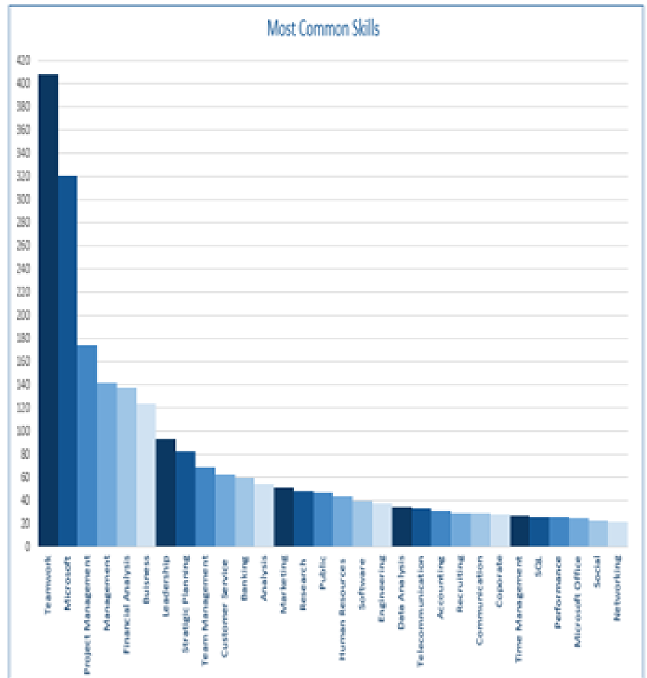

Fig. 9. The Most Commonly used Skills in the Four Clusters.

TF-IDF indicates the importance of the term for the whole document. It is related to the number of times the word appears in a document compared with its frequency in the document. Thus, Tf in TF-IDF weight measures the frequency of the terms in a document, while IDF measures the term importance in the document. The following equation illustrates the TF-IDF method.

$$tfidf_{i,j} = tf_{i,j} \times \log(\frac{N}{df_i}) \quad (1)$$

$tf_{i,j}$ = number of occurrences of i in j.

df_i = number of documents containing i.

N = total number of documents.

Therefore, the importance of a word increases with the value of TF-IDF for that word. Thus, the higher the TF-IDF value for a specific skill in Cluster, the higher the value of this skill will be, and likewise for the courses data set, vice versa.

2) Similarity measure: In order to begin the recommendation process, the similarity between each of the four clusters should be measured with the courses in the course dataset. In this step, one of the most popular metrics used to measure similarity is the cosine similarity [32]. The formula is:

$$similarity = \cos(\theta) = \frac{A.B}{||A||||B||} = \frac{\sum_{i=1}^{n} A_i B_i}{\sqrt{\sum_{i=1}^{n} A_i^2 \; \sum_{i=1}^{n} B_i^2}} \quad (2)$$

The similarity of each cluster is measured using the ten most similar courses in the course dataset. After that, these ten courses are presented as user recommendations in this cluster; this proceeds for all four clusters.

Subsequently, ten-course recommendations are presented for each cluster based on the results of cosine similarity, which are the top 10 similar courses for each cluster. Table VII represents the recommendations resulting from the four clusters.

TABLE VII. THE RESULTED RECOMMENDATIONS FOR EACH CLUSTER

Cluster ID	**Recommendations**
Cluster 1	Building Excel Online Automation with Office Scripts Building Websites with HTML, CSS, and JavaScript: Getting Started Build Your First Dashboard with GoodData How Novices Learn to Program: What I've Learned Teaching in a Coding Bootcamp Gin: A Website Application Framework for Go Organizational Design: Going from Features to Experiences: Front 2019 Exploring Product Sales Unlocking Unstructured: Leveraging Data Discovery Creating and Using Track Mattes in After Effects AWS Infrastructure with Python: Getting Started
Cluster 2	PMP® Exam Prep â€“ Project Human Resource Management Introduction to Presentation Design PMPÂ® Exam Prep â€“ Project Communications Management Computing, Communication, and Business Integration for CASP (CAS-002) Managing Delivery of Your App via DevOps Leveling up Planning and Designing Microsoft Azure Networking Solutions Website Performance LinkedIn Fundamentals Creating Animated Web and Social Media Banners in Photoshop and Flash
Cluster 3	Building Your Cyber Security Vocabulary Cyber Security Awareness: Malware Explained Cyber Security While Traveling Layer 2 Security for CCNA Security (210-260) IINS The Issues of Identity and Access Management (IAM) Incident Detection and Investigation with QRadar CompTIA Security+ (2008 Objectives) Cyber Security Awareness: Social Engineering SSCPÂ®: Monitoring and Analysis & Risk, Response, and Recovery (2012 Objectives) Preparing for the Google Cloud Professional Cloud Architect Exam
Cluster 4	Driving Engineering Culture Change at Microsoft: An Experimental Journey Scalable, Flexible, Modular, Preventative Architecture Agile Estimation Managing Work with Team Foundation Server 2012 Testing AngularJS from Scratch Easily Estimate Projects Using Statistics and Excel Secure Software Development CISSPÂ® - Software Development Security Windows 2000 Server Group Policy Java: JSON Databinding with Jackson

IV. EVALUATING MR-LI APPROACH

At first, we used experts to carry out the recommendation process manually. We asked the experts to separately provide ten-course recommendations for each cluster by matching the skills in each cluster to the most appropriate courses based on the course description. Then, we provide them with the four clusters and skills in each cluster, with the weight of each skill besides the courses. The experts generated ten ordered recommendations for the four clusters. Next, to evaluate the performance of the proposed approach, we compared the results generated from the approach against the results from the experts. By comparing the results, we find that only two cases result from comparing the recommendations. The first is that the approach's recommendation matches the human recommendation, and we refer to this case as true (true is quantified by 1). The second case is the opposite: the experts give a recommendation that does not match the recommendation resulting from the approach; we refer to this case as false (false is quantified by 0).

In order to achieve this, we created two empty lists, "T" and "F", one for the values of the ones, the other for zeros, and to do this between results, the comparison is based on the equality of the match results in both ways; thus, if a recommendation from cluster1 for the approach as an example exists in cluster1, then the recommendation is correct. The value of '1' will be added to the "T" list, in the other case, it is a false recommendation, and '0 'will be added to the "F" list, and at the end, the accuracy is the number of correct recommendations divided on the total number of recommendations. The following equation illustrates this process.

$$Accuracy = \frac{(T)}{(T)+(F)} \quad (3)$$

As a result, the accuracy of the proposed approach was 0.675. In addition to accuracy, other measures are used to evaluate the statistical result, namely precision and recall. Precision calculates the percentage of the related documents with the selected documents illustrated in Equation 4. In contrast, the recall measures the percentage of the related documents compared to all related documents found in the selected documents and is shown in Equation 5. Therefore, after applying accuracy and recall, we can apply F-Measure as shown in Equation 6. Table VIII shows the results.

$$P = \frac{TP_i}{TP_i + FP_i} \quad (4)$$

$$R = \frac{TP_i}{TP_i + FN_i} \quad (5)$$

$$F = \frac{2 \times P \times R}{P + R} \quad (6)$$

As a result, the F1 score was .81, which means we have an excellent working approach for our recommendations if we consider that we are treating strings matching (Skills / Courses). And for the precision, we are trying to find how much trues exist in the positives, but we have the false positives = 0, so the precision was 1, to make it clear, FP = 0, because the human way never recommend a course which is false for a certain skill, then the false = 0 and that's why precision = 1. Finally, the recall was 0.68.

TABLE VIII. THE PERFORMANCE RESULTS

	Precision	Recall	F1 Score
Cluster 1	1	0.50	0.67
Cluster 2	1	0.70	0.82
Cluster 3	1	0.80	0.89
Cluster 4	1	0.70	0.82
MR-LI	1	0.68	**0.81**

V. CONCLUSION

Social networks are extremely valuable in obtaining information that assists in modeling the user in a manner similar to reality. Therefore, LinkedIn, one of the largest professional social networks, provided customized course recommendations to users. These recommendations help users quickly reach the courses that suit their interests without requiring much search effort. This paper presents MR-LI as a course recommendation approach that relies on clustering algorithms to group the users according to their LinkedIn skills, resulting in four dataset clusters. Subsequently, feature vectors are extracted using TF-IDF for the user datasets and course datasets. The similarity was measured between each cluster's feature vectors and the courses using cosine similarity. The resulting ten recommendations were presented for each cluster based on the highest similarity. Finally, the proposed approach was evaluated by comparing the results with the human recommendations using experts. As a result, the F1 score of the proposed approach was .81. In the end, we faced some limitations in this research, including the lack of research that contributes to users modeling based on LinkedIn profiles in general, contributing to providing customized recommendations based on LinkedIn profiles in particular.

VI. FUTURE WORK

For future work, we will consider implementing this approach with some enhancements, including:

- Implementing the proposed algorithm in Arabic.
- Modeling users utilizing other LinkedIn sections, such as education and experience, and then comparing them.
- Evaluating the proposed algorithm after including it in one of the MOOC platforms.

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Constructing IoT Botnets Attack Pattern for Host-based and Network-based Platform

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***Abstract*—Internet of things (IoT) is the things or devices with software, intelligent sensors interconnected via the internet to send and receive data with another device. This capacity makes things, i.e., smartphones, smart homes, intelligent toys, baby monitors, IP cameras, and many more to act as intelligent devices like artificial intelligence (AI) and be utilized in the everyday life-world widely. IoT has enormous expansion potential, and many challenges have been acknowledged but are still open today. The botnet is a collection of bots from IoT devices used to launch extensive network attacks. In addition, rapid growth in technology has led to an incomplete understanding of IoT. The increasing number of IoT devices has led to the spread of malware targeting IoT devices make IoT Botnet behaviors challenging to identify and determine. To detect these IoT Botnets, a preliminary experiment on flow analysis is necessary. This paper is to identify IoT Botnet attack patterns from the IoT Botnet behavior that get from IoT Botnet activities. Therefore, this research is to identify IoT Botnet attack patterns in a host-based and network-based environment. First, this paper contributes to discovering, recognizing, categorizing, and detecting IoT Botnet activities. Next, organizing information to have a better understanding of the IoT botnet's problem and potential solutions. Then, construct the IoT Botnet attack pattern by analyzing the characteristics of the IoT Botnet behavior. This IoT Botnet attack pattern divides into two environments which are host-based and network-based. As a result, this paper aims to inform people about the attack pattern when the IoT device has been infected and become part of the botnet.**

***Keywords*—IoT; botnet; IoT botnet; host-based; network-based**

I. INTRODUCTION

Internet of things (IoT) is the things or devices with software, intelligent sensors interconnected via the internet to send and receive data with another device. This capacity makes things, i.e., smartphones, smart homes, intelligent toys, baby monitors, IP cameras, and many more, act as intelligent devices and widely be utilized in the everyday lifeworld. For instance, a smartphone can be streaming any melody that can be searched from the worldwide song, even though it's not in the storage of that smartphone. Besides smartphones, the intelligent home recently received much attention from the public, such as in [1]–[3] as it has been put into action as IoT devices. Moreover, Botnet is the short form of robot and network as claimed by [4],[5]. In addition, Botnets can compromise any machine system and become bots, automatons, drones, or zombies, from an assortment of computers infected with a malicious program [6]–[8].

This paper is to identify IoT Botnet attack patterns. The paper's goal is to identify IoT Botnet attack patterns in a host-based and network-based environment. Subsequently, the paper title Discovering IoT Botnet Detection Method: A Review [9] proposed placing IoT Botnet attack improved generic taxonomy. To detect these IoT Botnets, a preliminary experiment on flow analysis is necessary. The primary purpose of this experiment is to identify IoT Botnet attack patterns in a host-based and network-based environment. Then, the integration of the integrated analysis approach with static and dynamic analysis approaches has been performed. The integrated analysis will be used in profiling IoT Botnet attacks and characteristics. Then, the findings of both studies resulted in attack pattern identification and integrated analysis are contributed to IoT Botnets' attack patterns.

The flow of this experiment starts with discovering, recognizing, categorizing, and detecting IoT Botnet activities; Second, organizing information to have a better understanding of the IoT botnet's problem and potential solutions. The third step is data collection. The dataset used is IoT-23 since it provides real-world network information and a massive dataset of real-world and categorized IoT Botnet; fourth, analyzing the characteristics of the IoT Botnet behavior. Fifth, construct IoT Botnet attack pattern divides into two platforms which are host-based and network-based. As a result, this paper proposed a general IoT Botnet attack pattern for host-based and network-based platforms.

The expected output is the proposed general IoT Botnet attack pattern for host-based and network-based platforms using a dataset from IoT-23 [10]. From this dataset, the IoT Botnet attack pattern is constructed in two environments which are host-based and network-based. Therefore, even though this paper will face many constraints, but the expected output can be achieved. Crucially, the proposed is for developing the improved IoT botnets detection technique. Furthermore, this IoT Botnet attack pattern is constructed because nowadays, IoT has been used widely, as shown in Fig. 1. The Internet of Things is the decisive technology, as stated by Deloitte Global analysis [11].

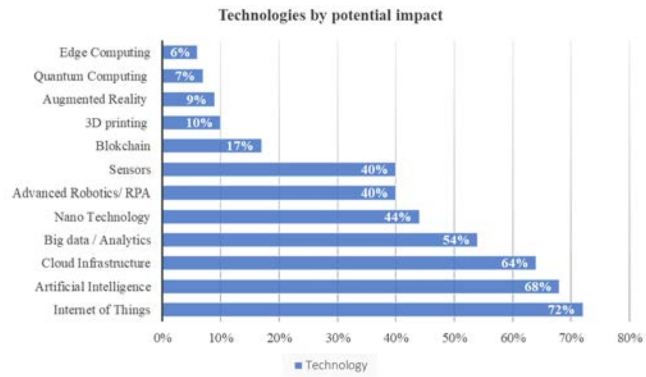

Fig. 1. Static Technology by Potential Impact in Industry 4.0 from Deloitte Global Analysis [11].

This paper has four sections, the Section I is the introduction of this paper consist of background, problem statement, objectives, and improvement of IoT Botnet. Next is Section II, which discusses the related work from previous research based on IoT devices infected by malware. Then, in Section III, discuss the methodology and implementation of this paper consist of the analysis process, data preparation, IoT Botnet experimental approach, IoT Botnet behavior for host-based and network-based platform, and present the proposed general IoT Botnet attack pattern for host-based and network-based platform. Lastly, section IV discusses the conclusion of this paper, limitations, and further work of this research.

II. Related Work

The Internet of Things is the things that are being connected with the internet. When something is connected with the internet, that implies it can send data, get data, or in both conditions. This capacity to send and receive data makes things brilliant such as a smartphone for instance. A smartphone can tune any melody that can be searched from the worldwide song, even though it's not in the storage of that smartphone. Yet, your telephone can send data by requesting the tune and afterward get data and streaming that tune on the telephone.

The next example is IoT of the home, which is a smart home; there are numerous studies and articles on the smart home. One of all these is the Implementation of IoT in a smart home [1]–[3] in this paper makes two systems, the first system is energy efficiency systems and the second is security systems. It links all devices to a device known as an intelligent central controller. For each device, this device is linked to a switch module. Then, connect to the router to access the Internet to communicate with the user, if necessary, if a license is needed. Smart Homes are just a network of devices that are used in daily life and other sensors which help to make life easy [1]. Devices communicate with each other but in reality, all devices communicate information to the smart central controller which then due to triggers and other programmed modifications the setting of other devices.

According to Table I, IoT devices include [12] IP cameras, motion sensors, smart bulbs, smart switches, and smart plugs. Next, [13] using this IoT device Danmini, Ennio, Ecobee, Philips B120N/10, Provision PT-737E, Provision PT-838, Simple Home XCS7-1002-WHT, Simple Home XCS7-1003-WHT, and Samsung SNH 1011N. Next, type of IoT device is used in toys, such as Hello Barbie, Furby Connect, Toy-Fi Teddy, and I-Que Intelligent Robot [14], [15] state that surveillance cameras are used in the experiment while [16] used Central hub, Lightbulb, Power switch, Motion sensor, Security cam for the testbed. In this journal [14], using toys that can be connected to the internet. The toys can be attacked by malware, it is because the toys using the open port to update information on the internet. These toys don't have login and passwords just need an internet connection to use. These toys also can be dangerous because they can take personal information by asking, listen and talk to the children with the basic information. This toy can talk with each other as a two-way connection. It contains sensors such as speakers, a microphone, and a camera. So, it can be easy for the hacker to attack when the device is not actively protected.

Furthermore, the Philips B120N/10 baby monitor from [13] has been reported for eavesdropping and espionage against other devices with a microphone or camera. This device can collect the data and samples from the user devices to harm the user in multiple ways. From this paper [12], [13], [15], [16], the device that recently been attack is Ip Camera and Security Camera. There are many reasons for Ip Camera can be easily attacked by malware. The first reason is the IoT devices have no security update because the developers take low priority in security. Next, the processing power and memory are expensive for implementing conventional cryptography. Furthermore, [12] state that IoT devices have weak login because the manufacture provides it for the users and using the default login. Some IoT devices leave open ports to support remotely. Lastly, Users often connect the device without going through the firewall. Therefore, this paper proposes to identify IoT Botnet attack improved generic taxonomy. Crucially, the proposed is developing the improved IoT Botnet detection technique.

TABLE I. Related Work

Author, years	IoT device
Kumar & Lim, 2020 [12]	IP cameras (D-Link) Motion sensors (D-Link) Smart bulbs (Philips Hue) Smart switches (WeMo) Smart plugs (TPLink)
Tzagkarakis, Petroulakis, & Ioannidis, 2019 [13]	Smart Doorbell Face Recognition (Danmini) Smart Door Phone (Ennio) Smart Home (Ecobee) Smart Baby Monitor (Philips B120N/10) IP Camera (Provision PT-737E) IP Camera (Provision PT-838) Security Camera (Simple Home XCS7-1002-WHT) Security Camera (Simple Home XCS7-1003-WHT) Smart Webcam (Samsung SNH 1011N)
Viding, 2019 [14]	Smart Toys (Hello Barbie) Smart Toys (Furby Connect) Smart Toys (Toy-Fi Teddy) Smart Toys (I-Que Intelligent Robot)
Shouran, Ashari, & Kuntoro, 2019 [15]	Surveillance cameras
Sun, Gong, Shea, & Liu, 2018 [16]	Central hub Lightbulb Power switch Motion sensor Security cam

III. Methodology and Implementation

Based on Fig. 2, the experiment's flow begins with the use of recording methods that are used in data collection processes. Before the malware samples are executed, both tools will begin capturing network traffic. Following malware execution, the data analysis process will begin by examining data from both tool-based results. The Wireshark tool will generate a large number of packets capture call as PCAP files, while the Process Monitor tool from the testing environment will generate a massive data log to reduce the studying workload for raw data and processed data, each of the data will be studies using a filter provided by the tools.

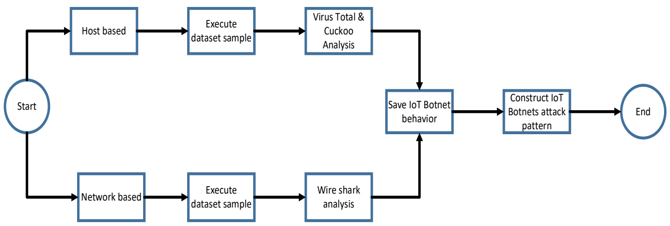

Fig. 2. Flowchart of the Analysis Process.

Fig. 2 depicts the overall analysis process, which begins with the analysis of each IoT Botnet infected folder. There were two levels of analysis approach which are host-based and network-based. The approach analyses network packet captured and on every single host log to control whether the payloads are spam or malicious. But if it corresponded follows unusual conventions or to a remote check for vulnerabilities not follow to standard IoT Botnet options. The integrated analyzer, as shown in Fig. 2, works by taking two perspectives into account: the host-based level and the network-based level. The host logs were examined at the host level using the file system monitoring, registry monitoring, and log monitoring characteristics. As an alternative, the characteristics of the full-payload from a network packet have been investigated at the network level as refer to MIT Lincoln Lab [6].

To detect these IoT Botnets, a preliminary experiment on flow analysis is necessary. The primary purpose of this experiment is to identify IoT Botnet attack patterns in a host-based and network-based environment. Then, the integration of the integrated analysis approach with static and dynamic analysis approaches has been performed. Static analysis function as examines the application or internet structure as compared to functional testing. Besides, the dynamic analysis is performed when the application programmed is running refer to MIT Lincoln Lab [6]. The integrated analysis will be used in profiling IoT Botnet attacks and characteristics. Then, the findings of both studies resulted in attack pattern identification and integrated analysis are contributed to IoT Botnets' attack patterns.

The methodology of overall analysis process is illustrated in Fig. 3 started by preparing dataset. Stratosphere Laboratory [10] is a dataset used in this study and labeled dataset of malicious IoT network traffic. Next step is overview of IoT Botnet experimental approach. This research analyzes the IoT Botnet attack pattern based on host and network environment. Then, the general approach used in the experiment, hardware, and software used, and datasets used for both analyses is discussed. In addition, the third step is IoT Botnet analysis flow. Technically, the analysis is divided into two parts: attacking pattern analysis and integrated approach analysis. The next following segment discusses the analysis of IoT Botnet attack pattern host-based and network-based platform that have been evaluating and generalized in detail. Lastly, proposed general IoT Botnets relationship model for host-based and network-based platform. Therefore, the goal of this research is to identify IoT Botnet attacks pattern and improved generic taxonomy.

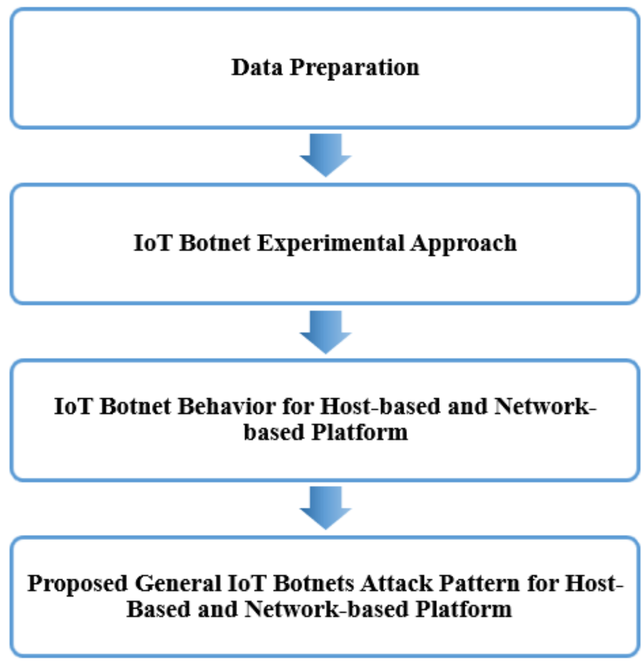

Fig. 3. Methodology.

A. Data Preparation

The data consists of real IoT malware infections as well as benign IoT traffic. Stratosphere Laboratory [10] is a dataset used in this study and labeled dataset of malicious IoT network traffic. This study makes use of seven data points from this dataset. In each situation, an exact or real malware was executed in a Raspberry Pi, which was used to make various actions and various protocols. Table II summarizes the characteristics of each scenario, and the malware used to infect the device. The details of a table can be seen in Table II. The dataset used is IoT-23 since it provides real-world network information and a massive dataset of real-world and categorized IoT Botnet. This dataset uses the updated IoT device, the duration of the experiment is 8 to 24 hours, and the dataset use the real IoT Botnet malware.

The dataset IoT Botnet network traffic is shown in Table II. The actual IoT network traffic is collected on two levels: host and network. The host-based level was selected based on the monitoring attack performed on its host as well as the actions that occurred within a suspicious activity for that host. Meanwhile, one important reason to choose network-level capture is that monitor network traffic for specific network devices to detect suspicious activity that studies network and protocol. To detect bots accurately, host-level and network-level analyses had to be developed. These two types of analyses balance individually in detecting malevolent activity in the IoT Botnet network. As a result, the network packets captured in this study originate in both a host and a network environment.

TABLE II. IoT BOTNETS DATASETS SUMMARY

Name of Dataset	Duration (hrs)	#packets	#zeekFlows	Pcap size	IoT Botnet type
CTU-IoT-Malware-34	24	233000	23146	121MB	Mirai
CTU-IoT-Malware-44	2	1309000	238	1.7GB	Mirai
CTU-IoT-Malware-49	8	18000000	5410562	1.3GB	Mirai
CTU-IoT-Malware-48	24	13000000	3394	1.2GB	Mirai
CTU-IoT-Malware-9	24	6437000	6378294	472MB	Linux. Hajime
CTU-IoT-Malware-42	8	24000	4427	2.8MB	Mirai
CTU-IoT-Malware-35	24	46000000	10447796	3.6G	Mirai

Clarification of the experimental method and each dataset is used in the study. Based on Table II, the network traffic capture is from these three types of IoT devices to get real network which are the Amazon Echo that uses as a home intelligent private assistant for the owner's home, a Somfy which is a smart door lock that automated, and Philips HUE which is the smart lamp. It is significant to note that the three Internet of Things devices is actual devices of hardware, not simulations. The use of real devices of IoT tolerates for the capture analysis of real network attacks from simulated traffic. The malicious scenarios, like any other genuine IoT device, operate in a controlled network environment with unrestricted internet access. By running a specific piece of malware on a Raspberry Pi, the malicious scenarios were created. Mirai and Hajime traffic are included in this dataset. Malware captures are carried out over extended periods.

B. *IoT Botnet Experimental Approach*

This research analyzes the IoT Botnet attack pattern based on host and network environment. Existing IoT Botnet detection techniques were classified and profiled based on their technique, criterion, platform analyses, and previous framework. In this section, Fig. 4 shows the illustration of the IoT Botnet testbed in detail to collect the sample malware. This IoT Botnet testbed has three steps to setup the testbed.

The first section of the IoT Botnet testbed is the network configuration used in this experiment refers to the network simulation and formally has been modified using Linux and Windows 7 to suit the testbed experiment of this research. The experimental testbed lab is used to monitor the activities of the IoT Botnet. This testbed was carried out in a controlled setting. The network design depicted in Fig. 4 illustrates the network testbed proposal used in this research, which is comparable to [8], [17], [18]. This research replicates their design of experiment due to the success achieved. As a result, the testbed design consists of 1 router, 2 switches, 4 personal peers or computers with new installations of Windows and Linux, 1 server to complete the packet capture method and one NTP server. Several software specifications are essential to help make the project succeed.

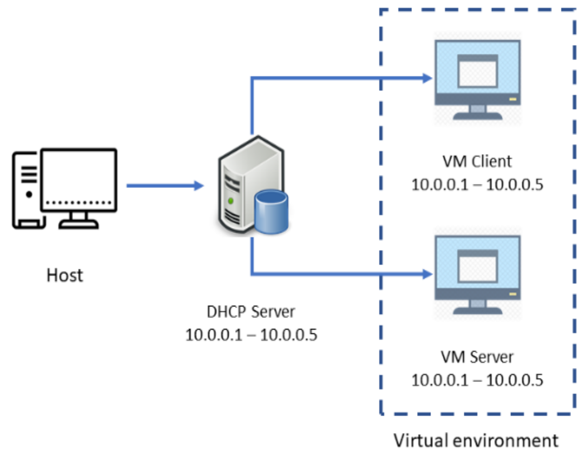

Fig. 4. IoT Botnet Testbed.

There are four softwares that are used in this experiment. The first software is Cuckoo Sandbox, an open-source security program for suspicious file security. Moreover, it uses custom components that track malicious process activity when operating in an isolated environment. The second software is Virus Total, an online system that provides antivirus engines and website scanners to analyze files and URLs to detect viruses, worms, trojans, and other types of malicious content. This can also be used to spot false positives. Last software is Wireshark, a packet analyzer for networks. An analyzer of network packets provides as much information as possible about the captured packet data. Thus, the overview of the IoT Botnet Experimental Approach for this research to identify IoT Botnet attacks pattern and improved generic taxonomy.

C. *IoT Botnet Behavior for Host-based and Network-based Platform*

This section discusses the IoT Botnet behavior for host-based and network-based platform. In a host-based approach, [17], [19] monitoring behaviors are carried out in a single host, and events for suspicious activity occur within that host. The data is simulated from Virus Total for the file system. The network-based analyzed the full payload packet data framework using Wireshark. This tool is the effective network analyzer for the network based. This section identifies C&C servers and infected hosts in the network. Data is collected at each peer and throughout the traffic. Each peer produces a security log, a system log, and an application log. The service generates network traffic using tcpdump. Wireshark and tcpdump are used to verify traffic between specific hosts at the network level. There are seven datasets which are CTU-IoT-

Malware-34, CTU-IoT-Malware-44, CTU-IoT-Malware-49, CTU-IoT-Malware-48, CTU-IoT-Malware-9, CTU-IoT-Malware-42, and CTU-IoT-Malware-35. The Host-based data can be simulated from Virus Total while the network-based is simulated from the Wireshark. Therefore, this section discusses IoT Botnet behavior for host-based and network-based platform.

1) Host-based: In a host-based approach, [17], [19] monitoring behaviors are carried out in a single host, and events for suspicious activity occur within that host. The overall system behavior continuously records each host monitor. All host been observed by the log monitoring. All abnormal behaviors and characteristics will be identified in every single activity that occurred in the host. The Host-based data can be simulated from Virus Total. From the seven dataset CTU-IoT-Malware-44 are the best datasets that illustrate the attack pattern for host-based platform as shown in Table III.

TABLE III. IoT Botnet Behavior for Host-based Dataset

IoT Botnet data	Filed open	File written	File copied	File dropper
CTU-IoT-Malware-44 (Mirai)	locale.alias	.dat.nosync100c.Y3KZqJ	.dat.nosync100c.Y3KZqJ	/System/Library/CoreServices/pbs
	en_US.UTF-8	mdsDirectory.db_	mdsObject.db_	
	en_US.utf8	.dat.nosync0fa1.JacR1I	.dat.nosync0fa1.JacR1I	
	en_US	mdsObject.db_	mdsDirectory.db_	
	en.UTF-8	com.apple.smb.server.plist-lock	A66DD831-8DB9-49C7-85C6-87F3F660A041.perfd.events.XXXXXX.stats	
	en.utf8	supportedCountriesTraffic-5.plist	networkDefaults.plist	
	en	default-shields-index-extralarge-70.shieldindex	ResourceManifest.pbd	
	.CFUserTextEncoding	ResourceManifest.pbd	default-16637.styl	
	com.apple.nsservicescache.plist	hybrid-1426.styl	default-search-3806@2x.styl	
	AppleInternal	default-genericshields-extralarge-6.genericshieldstyles	globe-default-1522.styl	
	com.apple.NSServicesRestrictions.plist	default-shields-index-large-88@2x.shieldindex	hybrid-1425@2x.styl	

The Experiment data was tabulated as Table III and classified into four columns that are FileOpen, FileWritten, FileCopied, and FileDropper. The data from Table III simulated from Virus Total for the file system. FileOpen is a function that opens a file named and flagged with the given name and flag. The IoT Botnet samples are injected into the FileOpen, which initiates the creation of an IRC channel for infected clients to join. When opening a FileOpen encrypted document in Adobe Acrobat or Adobe Reader, the FileOpen plugin is only available. It contains no spyware or malware, leaves nothing running on the machine, and makes no changes to the Windows registry or system files. The FileWritten function is designed to write data information into a CSV folder automatically. The character “rn” will be shown at the end line, after writing into the file. The message is either a string expression or a number that contains the text that is written to the file. The following function, FileCopied, copies the first file which is the original file from a local or shared folder to a different file. FileCopy.exe is an executable file included in the IObit Advanced SystemCare Ultimate 8 programmed. The software is typically 498.97 KB in size. Finally, FileDropper is a type of Mirai (Trojan) that some type of malware designed to install such as backdoor and virus; on a target device system.

Based on the result of this research, the IoT Botnet attack sample showed similarity and unique behavior during the experiment. In the lifecycle of IoT Botnet, typical IoT Botnet showed the process that will be downloaded by using one of the methods which are file dropper, mail attachment, or drive-by download before execution of the malware. Since the IoT Botnet samples are already downloaded from infected devices after the experiment was launched, IoT Botnet's initial lifecycle behavior for this experiment may be negligible. The bots can contact the infected machines by IP address. The data product form and rundown of known bots to reach the bots’ answer. The bot will remove the record and refresh if one of the bots' forms is lower. Thus, the rundown of each bot for the infected devices will develop and updates itself immediately into single known bot. As IoT botnets keep on developing, being utilized dispatch DDoS assaults. Since IoT gadgets are Linux and Unix-based frameworks, they frequently are focuses on executable and linkable arrangement format ELF binaries, a typical record design found in inserted frameworks' firmware. The malware conveyance strategy regularly targets SSH or Telnet network conventions by misusing default, hardcoded accreditations. Once undermined, the malware payload is conveyed to the gadget for enlistment into the botnet. Thus, the existing IoT Botnet detections based on host-based techniques were classified in terms of are FileOpen, FileWritten, FileCopied, and FileDropper.

2) Network-based: The network-based analyzed the full payload packet data framework using Wireshark. This tool is the effective network analyzer for the network based. This section identifies C&C servers and infected hosts in the network. This section of the analysis focuses on defining the unique communications to form IoT Botnet malware, IP address, Port number and protocol over a suspicious port. The detecting any indication of malevolent activity attack that attempts the network, and identifying which IoT botnets are on the infected network host. From the seven dataset CTU-IoT-Malware-34 are the best datasets that illustrate the attack pattern for network-based platform as shown in Table IV.

TABLE IV. IoT BOTNET BEHAVIOR FOR NETWORK-BASED DATASET

Dataset	IoT botnet	IP Address	Port Number	Protocol
CTU-IoT-Malware-34	Mirai	185.244.25.235	6667	IRC
	script bots	192.168.1.195	48986	IRC
	amplified attacks			
	netblocks			
	Spoof			
	AmpAttacks	66.67.61.168	63798	TCP
	Tragedy	1.1.1.1	1	TCP
	bot-master AmpAttacks	50.50.50.53	53	TCP
	tripsit.me	192.223.29.150	62351	TCP
			80	HTTP
	Bot Master Spoof	71.61.66.148	65279	TCP
	Bad packets (Mirai like Botnet host)	116.220.1.247	-	TCP
	bot-master shadoh	123.59.209.185	80	TCP
	STD Dos	74.91.117.248	5376	UDP

The network-based pattern is extracted from full payload network traffic that captured the whole activity of IoT Botnets. The pattern is studied in the protocol used, suspicious port, suspicious IP address, and attack that have been launched. The IoT Botnets attack pattern at the network level is summarized in Table IV. The summary then has been discussed in this section. The dynamic analysis, for the first phase the controlled environment has been implemented known as IoT Botnet testbed environment. The static analysis had been done in reviewing the real codes of infected files to reveal and study their true characteristics. In the dynamic approach, the capabilities are highly concerned with the detection of malicious activities during or after program files execution. The IoT Botnets' activities are captured through the event host logs and whole network traffic.

Subsequently, the dynamic analysis is performed on the event host log and network traffic datasets. The IoT Botnet test bed setup applied by controlled environment where the datasets were collected. Process monitors and process explorer capture the event host log to gather information on the localhost. Meanwhile, the tcpdump service has captured the overall network traffic. Through this dataset, the IoT Botnets' attack and characteristics are fully observed to ensure the interaction on the botnet's server and the effect on each of the infected files to a real environment. After that, the integration of analysis results on static and dynamic analysis will be correlated together to construct the basic and general attack model of IoT Botnets. This research analyzes the IoT Botnet attack pattern for host-based and network-based platform. Thus, the existing IoT Botnet detections methods were classified and profiled in terms of analyzing IP address, port number, and Protocol.

D. Proposed General IoT Botnets Attack Pattern for Host-based and Network-based Platform

This section proposed general IoT Botnets attack pattern for host-based and network-based platform. This proposed based on these seven datasets which are CTU-IoT-Malware-34, CTU-IoT-Malware-44, CTU-IoT-Malware-49, CTU-IoT-Malware-48, CTU-IoT-Malware-9, CTU-IoT-Malware-42, and CTU-IoT-Malware-35. The proposed general IoT Botnets attack pattern for host-based platform consists of FileOpen, FileWritten, FileCopied, and FileDropper, it considered as risky event process that happens to allow the attacker in operating systems, replace the original files. Next, the proposed general IoT Botnets relationship model for network-based platform consist of IoT Botnet malware, IP address, port number, and protocol. Therefore, this section discusses the proposed general IoT Botnets attack pattern for host-based and network-based platform.

1) Proposed general IoT botnets attack pattern for host-based platform: The generic IoT Botnets attack pattern and integrated approach as described in the earlier section are utilized to construct the IoT Botnets attack pattern. For the finest of information, there is no published study has been found that performs the IoT Botnets attack pattern model based on the file system for the host-based. As a result, this study implemented the IoT Botnets attack pattern model following the proposed IoT botnets attack pattern for the host-based based on a file system. The following section describes the details Fig. 5.

Fig. 5. Proposed General IoT Botnets Attack Pattern for Host-Based Platform.

The static analysis began with isolating the experimental setup in a controlled environment. The ability to detect malicious activities by static analysis before the execution of programmed files and then implement the data in Virus Total. The operation processes involved in all IoT Botnets infected files have been created as its main process start. The information of IoT Botnets infected files has been discovered in four main components. The proposed model consists of FileOpen, FileWritten, FileCopied, and FileDropper for the host-based as shown in Fig. 5, are considered as risky event process that happens to allow the attacker in operating systems, replace the original files. Here, malicious activity attempts to exploit the victim host to create an.exe file and remove essential files in the system directory. Otherwise, the frequent changes in the registry had been noticed as a high possibility of malicious activity has arisen. The specifics are as follows: The IoT Botnet samples enter the FileOpen, which creates an IRC channel for infected clients to join. The FileWritten function is designed to write data information into a CSV folder automatically. The character "rn" will be shown at the end line, after writing into the file. The following function, FileCopied, copies the first file which is the original file from a local or shared folder to a different file. Finally, FileDropper is a type of Mirai for Trojan that some type of malware designed to install such as backdoor and virus; on a target device system.

2) Proposed general IoT botnets attack pattern for network-based platform: The network-level pattern is extracted from full payload network traffic that captured the whole activity of IoT Botnets. The pattern is studied in a protocol used, suspicious port, suspicious IP address, and attack that have been launched. Generally, on a network level, the scanning activity is mainly concerned with a protocol. Both suspicious port and suspicious IP addresses can be found in exploit and C&C connection attack steps. The generalized attributes designed for exploit activity are concern with protocol and, destination port. The C&C connection considers the detection of IoT botnets and the C&C website as the attribute. Moreover, the generalized attributes for impact or effect steps allowed the attacker to launch an attack on a remote address attack. As a summarization of the generalized IoT Botnets attack patterns, the findings are relatively depicted in Fig. 6 based on the discussion in analysis of generalized IoT Botnets from a network-level perspective.

Fig. 6. Proposed General IoT Botnets Attack Pattern for Network-Based Platform.

The generic IoT Botnets attack pattern and integrated approach as described in the previous section are utilized to construct the IoT botnets attack pattern. For the finest of information, there is no published study has been found that performs the IoT botnets attack model. As a result, this study implemented the IoT Botnets attack pattern model following the proposed IoT botnets attack pattern for the network-based based on IoT Botnet malware, IP address, port number, and protocol. This research analyzes the IoT Botnet attack pattern for host-based and network-based platform. The existing IoT Botnet detections methods were classified and profiled in terms of analyzing IP address, port number, and Protocol.

Based on the proposed pattern, show the general IoT Botnet attack pattern analysis. From the finding have been referred to develop new IoT Botnet attack pattern. This IoT Botnet attack pattern has been designed for host-based and network-based. The host-based attack pattern provides explanation for the IoT Botnet attacks aims and strategies in protecting from the attack. Practically, the attack pattern provided by researchers to identified the bot server and botmasters. While the network-based pattern is used to identify the method of network attack by the Botmaster. Overall, this paper was effective in recognizing the characteristics and behavior of IoT Botnet for host-based and network-based. The result was improved outcomes to researchers to create a new IoT Botnet attack pattern.

IV. Conclusion and Further Work

In conclusion, the researchers have studied the host logs data and network traffic data to determine the attack pattern from host-based and network-based perspectives. The attack pattern serves as a guide for administrators in determining who the true attacker is behind the scenes. The analysis's output is proposed as the general IoT Botnets attack pattern on the host and the general IoT Botnets attack pattern on the network. Furthermore, this paper also presents the integrated approach to studies and classify the whole IoT Botnets activities and events to recognize the attack pattern and characteristics of IoT Botnet. This study combines static and dynamic analysis approaches to gain a better understanding of how IoT Botnets behaved in a real-world IoT network environment. The attack pattern and integrated analysis result are inherited to construct the basic and general IoT Botnets attack, pattern model.

This paper contributes to discovering, recognizing, categorizing, and detecting IoT Botnet activities. Next, organizing information have a better understanding of the IoT botnet's problem and potential solutions. Then, construct the IoT Botnet attack pattern by analyzing the characteristics of the IoT Botnet behavior. This IoT Botnet attack pattern divides into two environments which are host-based and network-based. As a result, this paper aims construct the attack pattern when the IoT device has been infected and become part of the botnet. The limitation of this research is the dataset from IoT-23 is bigger, and need more space to run the dataset. Therefore, the result for this paper has been accomplished and the aim objective has been complete. This is ongoing research in finding an effective technique to make the detection on IoT Botnets attack pattern. The further work for this research is developing the IoT Botnet attack pattern in graph degree theory. The graph degree theory will visualize the attack pattern of the IoT Botnet.

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A Classification of Essential Factors for the Development and Implementation of Cyber Security Strategy in Public Sector Organizations

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***Abstract*—To ensure the achievement of quality security to safeguard business objectives, implementing, and maintaining an effective Cyber Security Strategy (CSS) is crucial. Inevitably, we need to recognize and evaluate the essential factors, such as technological, cultural, regulatory, economic, and others, that may hinder the efficacy of a CSS development and implementation. From the literature review, it is evident that such factors are either abstractly stated, or only assessed from singular viewpoint and are scattered across the literature. Moreover, there is a lack of holistic studies that could assist us in comprehending the critical factors affecting a CSS. In this paper, we present a systematic classification of distinct, structured, and comprehensive list of key factors covering multiple aspects of an organization's CSS, including organizational, cultural, economic, legal and political, and security, to provide a more complete view of understanding the essentials and analyzing the aptitude of a planned or given CSS. The proposed classification is further evaluated to examine the critical factors verified by conducting semi-structured interviews from security experts in different public sector organizations. Furthermore, we present a comparison of our work with the recent attempts that reflects that a significant accumulation of essential factors have been holistically identified in this study.**

***Keywords*—Cyber security strategy; critical factors; risk treatment; culture; threats**

I. INTRODUCTION

This Cyber security is a vital concern for both the public and private sectors. However, the public sector is unique as it comparatively has a vast IT infrastructure covering a broader and general user base [1]. Public sector organizations have experienced targeted attacks continuously and increasingly [2]. Around 70% of breaches target public or government organizations [3].

Security is becoming harder to manage in today's dynamic information systems and necessitates an efficient strategy to deal with the adverse incidents and to protect the organization from the potential risks [4]. A Cyber Security Strategy (CSS) is a long–term high-level plan designed to achieve security goals to ensure that the business meets its set objectives, mission, and vision effectively [5]. It provides a collection of frameworks, procedures, and corresponding objectives that aim to achieve certain quality in securing the organization infrastructure and operations.

As stressed in [6] and [7], CSS is very important to the public sector because:

- Cyber-attacks in this domain is more permanent and their consequences can last for a long period.
- The public sector is composed of the most sensitive and critical infrastructure.
- There is a need to develop justifications for and foresee low risk investments of public funds in cyber security solutions and services.
- It will assist in implementing a uniform plan across the organization to protect public resources, and therefore assist in building and retaining a high-level public trust.

The reliance of technology for almost every single process in an organization has led to push CSS and its success factors to the top of the business agenda. A CSS can only be designed and implemented efficaciously, if we recognize and assess the corresponding influencing factors [8]. During our study, we found that there have been numerous efforts made in highlighting these factors however, their focus is either a particular aspect of business like regulatory needs and technical concerns, or abstractly identified in a particular operational infrastructure, e.g., healthcare. We couldn't find any appropriate study that provides a holistic and comprehensive classification or list of essential factors, which we can refer to for (re)consideration, while we plan to design and implement an effective CSS.

In this study, we present a classification of distinct and well-structured list of more than twenty essential factors that will help a public sector's organization to evaluate key business and operational aspects when designing or implementing their CSS. For every long-term planning, such as a CSS, it is vital to consider the major business contexts. This includes the human factors, regulatory and political contexts, economic capabilities, the potential threat landscape and its methodological management, etc. [9]. To ensure that our classification encompasses all major and mission-critical business themes, we developed our classification to include six principal classes as: Organizational, Cultural, Legal and Political, Economic, Technical, and Risk. Similar business themes are also stressed to be evaluated in [9-11]. This classification ensures that all the identified factors are aligned with and cover the vital concerns related to the key contexts of

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an organization. To further refine the factors and to highlight the critical ones, we have conducted open-ended semi-structure interviews. The interviews, comprising of seventy questions, were held with experts in the field to comprehend what they believe to be crucial factors for a successful CSS. Moreover, a comparative analysis is performed with the existing related work that shows that our classification provides a more comprehensive and complete list of factors, and provides an organization a broader view of the dynamics related to the development and implementation of an effective CSS.

The rest of the article is structured as follows: In Section 2, we summarize the area, factors and methodology used in the related work. The methodology used and results are detailed in Section 3. This section also highlights the reflection made on the critical factors identified. A comparison of the proposed classification with related work is provided in Section 4. Finally, the study limitations and conclusion are presented in Section 5.

II. Related Work

Several studies highlighted some of the factors that can influence the design and implementation of CSS. In this section, we have reviewed the most related literature. These works also form the basis of the proposed classification and are also used in the comparison.

Jalaai et al. [2] has explored the organizational perspective of cyber security in the Healthcare sector. The study followed a systematic literature review and focused on the most important aspects needed to tackle a successful strategy adopted for healthcare. The study highlighted and focused on organizational factors that also touched the technical readiness of the healthcare institutes. The factors identified in this study were software development security, disaster recovery planning and business continuity.

The human factor in the current cyber security landscape is studied by Benson et al. [12]. Using a systematic literature review, the authors outlined the most critical factors in human element domain are: Awareness, Individual Attitudes, Norms and Cultural context.

Fritzvold, in [13], has focused on the Cyber security in the organization with focus on the sectors of power distributions, railway and healthcare. The study followed a case study approach to explore the factors that directly or indirectly influence the cyber security posture in the mentioned domains. The key factors outlined in this work are: competence, compliance, awareness, leadership engagement and system technology management.

Awan et al., in [14], have studied the security strategies to overcome security measures, the authors pointed out the effective factors that influence the success of implementing such strategies to overcome such measures. Following a systematic literature review, the factors stressed are: Level of governance in critical information infrastructure (CII), level of protection, sharing of Cyber-security information and insufficient market preparation.

In [15], the authors studied the human factors in the information security culture and stated that the human factor has always been the weakest link when it comes to security enforcement. To strengthen this aspect, some procedures need to be taken into consideration. Following a systematic literature review, the authors included that the essential human factors that form the basis for a successful security program enforcement are: information security (IS) policy, deterrence, incentives, attitude, involvement, training and awareness and management support. The authors concluded that only employing technology-oriented security controls are not sufficient, and that people at all levels of the organization play an important role in bringing a positive value to the information security culture and therefore, should be assessed and addressed in any security program.

Khansa et al. [16], have followed two rounds of a qualitative survey to study the impact of organizational control in cyber environment. The study emphasized on exploring the relationship between employees' cyberloafing and formal organization control. Cyberloafing is defined as the surfing of employees over the internet for personal reasons during work hours [17, 18]. Such a behavior negatively affects the productivity and may lead to unwanted and severe security issues. The study suggested that that factors such as, attitude, subjective norms perceived, behavioral controls and lack of punishment. These factors play a vital role in designing organization controls that are crucial to be considered for any given CSS.

Ebenezer [19] studied how staff accessing, using and sharing published information online is conducted within the National Health Service (NHS) in England along with the potential impacts they may have on the trust of these services. The author makes use of semi-structured interviews and document analysis methods and shows risk factors that can adversely affect the security of these services are information manipulation, identity theft, insider, productivity loss and cyber-attacks.

Cooke [20] conducted a systematic literature review to identify the factors related to the success of strategies implemented in the public sector. The study concluded factors such as, IT skills, adequate funding, engagement to CSS, cybercrime law and public enlightenment programs are inevitable to be considered for a successful strategy.

Choejey et al. [21] explored the critical success factors for cybersecurity in government organizations in Bhutan. The authors conducted a questionnaire-based survey for data collection. The study concluded several critical factors needed for the successful implementation of cyber security. They are: awareness and training, security policy, budget, security audit, security responsibility, organization structure, change management, and communication and collaboration.

Peursum [22] studied the building blocks necessary for a security strategy from an organization perspective. The author adopted an expert interviews methodology to confirm data collected from the literature. The key factors highlighted are, systems, skills, staff, strategy, style shared value and structure.

While developing and implementing the cyber security strategy the alignment with business objectives should be taken into consideration. Developing a CSS is certainly not a single perspective task. It should be aligned with the organization's objectives and vision. It should also build the trust that needed to realize the objectives and protecting the organization from the cyber-threats [23]. The key factors and the focus area of the reviewed literature are summarized in Table I.

III. Methodology and Results

To achieve our objective of a well-defined and structured classification of the essential factors for an effective CSS, we have utilized two-step approach; first, to develop the classification, and second, to recognize the most critical factors.

A. *Factors Classification*

Firstly, a literature review method has been employed to devise a structured classification of the essential factors. This was necessary to collect the necessary factors, summarized in the Table I that are scattered across the literature, some of them were synonymous. For instance, awareness, public enlightenment programs, and training and awareness have the same meaning and objective, which need to be transformed to a common terminology. Similarly, as productivity loss, cyber-attacks, and insider threats represent instances of threats and attacks, they are accumulated in accordingly. Moreover, there was a need to re-label a few of them to widely recognized terminology in the context of CSS, e.g., "structure" needs to be resolved to organizational structure, which is less confusing and a more commonly known phrase. Therefore, to have a refined classification and to avoid the mentioned concerns in a systematic manner, we exercised the following steps in a process manner as shown in Fig. 1.

Factors are classified in accordance with essential business themes to ensure that all mission-critical contexts are appropriately addressed and are underlined as: Organizational, Cultural, Legal/Political, Economic, Technical, and Risk. By exercising the above listed steps, a set of 31 factors were finalized and mapped to the respective classes as illustrated in Fig. 2.

TABLE I. List of Identified Factors

Factor (Revised Label): [Study]	**Factor (Revised Label): [Study]**
1. Information Security Policy: [15, 21] **2.** Deterrence:[15, 24] **3.** Attitude (Attitude and Behavior): [15, 16, 25] **4.** Involvement: [15, 16, 26] **5.** Training & Awareness (Awareness): [12, 13, 15, 16, 21] **6.** Management Support: [15, 16] **7.** Identity Theft (Threats and Attacks): [19] **8.** Insider (Threat Actor): [19] **9.** Productivity Loss (Threat and Attacks): [19] **10.** Cyber-attacks (Threats and Attacks): [19] **11.** Information Manipulation (Threat and Attacks) [19] **12.** Behavioral Controls (Deterrence): [16] **13.** Lack of Punishment (Detterence): [16] **14.** IT Skills (Skills & Expertise): [20] **15.** Adequate Funding (Funding): [20, 21] **16.** Motivation (Involvement): [20] **17.** Cybercrime Law: [20, 26] **18.** Public Enlightenment Prog. (Awareness): [20, 26] **19.** Security Audit: [21] **20.** Security Responsibility (Due Diligence): [21] **21.** Change Mangement: [21] **22.** Structure (Organization Structure): [21, 22] **23.** Software Development Security (Application Security): [2] **24.** Disaster Recovery Planning: [2] **25.** Business Continuity: [2, 21]	**26.** Individual attitude and norms (Attitude and Behavior): [12, 25] **27.** Cultural based strategy (Strategy): [12] **28.** Compliance: [13, 27] **29.** Awareness (Awareness): [20, 26, 28] **30.** Leadership engagement (Management Support): [13] **31.** System Technology Management (Systems): [13, 22] **32.** Interest level of government on CII(Critical Information Infrastructure) (Govt. Interest): [14] **33.** level of protection: [14, 26] **34.** Insufficient market preparation (Competence): [14] **35.** Systems (Systems): [22] **36.** Skills (Skills and Experience):[22] **37.** Strategy (Strategy): [22] **38.** Style (Strategy): [22] **39.** Shared value: [22] **40.** Personality traits (Attitude and Behavior): [25, 29] **41.** Impulsiveness (Attitude and Behavior): [25] **42.** Computer skills (Skills and Experience): [30] **43.** Experience with CS practices (Skills and Experience): [30] **44.** Risk Posture: [29] **45.** Flexibility (Attitude and Behavior): [29] **46.** Ethical Attributes (Attitude and Behavior):[29] **47.** Connectedness (Collaboration): [29]

Fig. 1. Classification Development Process.

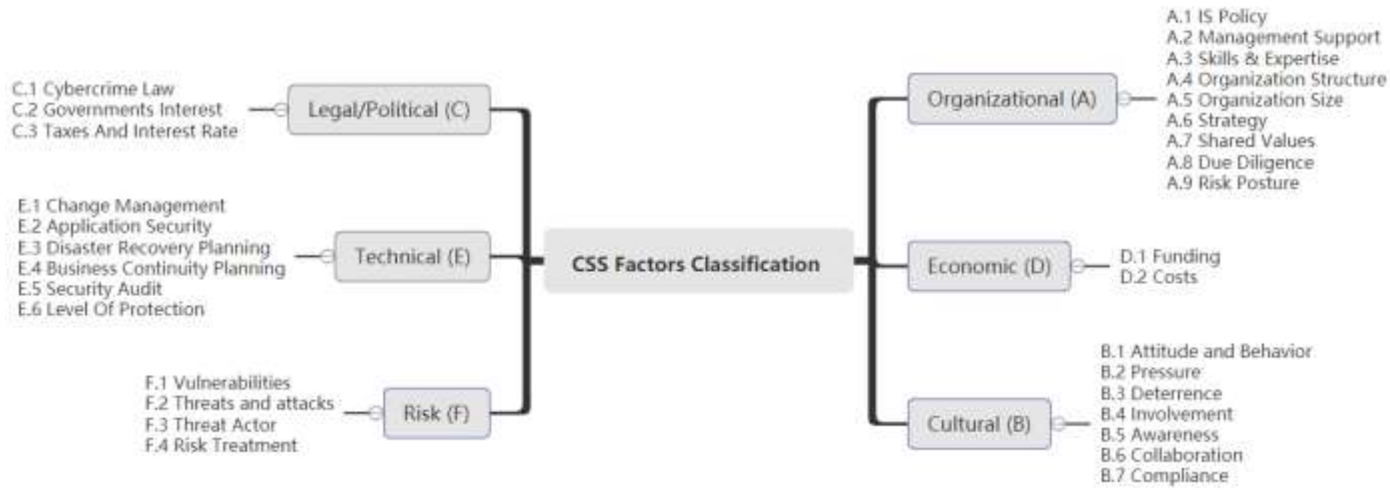

Fig. 2. Proposed CSS Factors Classification.

B. *Identifying Critical Factors*

Critical factors may vary from the type of organization to country or region they are operating in, as they might be influenced by their respective regulations, culture, threat spectrum, and other circumstances. In this study, we have explored critical factors in the context of public sector organizations working in Oman. We conducted open-ended and semi-structured interviews from a target group of ten participants to further refine and confirm these critical factors. Participants were selected based on the criteria such that they have at least a five years' experience in the security domain and have been involved in key business processes related to CSS at the organizational level in the public sector. A summary of the participants' profiles is highlighted in Table II.

Seventy questions were asked in each interview with at least two distinct questions to assess the importance (criticality) of each factor listed in the classification. The questions were validated using face validation and pilot testing with two experts, as suggested in [31] that assisted us to eliminate and modify the redundant and out-of-context questions. The interview sessions were recorded and transcribed into text, and analyzed using the Interactive Analysis Model [32]. A Likert-scale was then used to evaluate the overall feedback concerning the importance of a given factor. The importance scale used was: Very Important= 5, Important=4, Moderately Important=3, Less important =2, Unimportant= 1). Factors having an average value of 4 and above are characterized as critical. The factors criticality level of each factors with respect to each participant (P) response is depicted in Table III to VIII.

1) Organizational factors: As can be seen in Table III, Organizational Size, Shared Values, and Risk Postures were considered as no critical. The majority of the participants concurs that the organizational size does not affect the CSS development and execution as long as there is a clear structure, guideline, and resources available. Risk posture was dominated because the majority of participants acknowledged that they adapt from the existing standard risk management methodologies and practices as per their needs instead of defining and utilizing their own as it takes considerable time and effort to conclude it. Moreover, since shared values are motivated by the competitiveness in the market, it is less perceived in the public sector [33] and was therefore not acknowledged by the P2, which lowered its overall score in the class.

2) Cultural factors: From all the interviews conducted, as evident in Table IV, it was concluded that the majority of the participant, based on their experiences, believed that the employees' positive attitude, knowledge, and collaboration are critical to complete tasks in a teamwork. Employee compliance with the organizations policy and rules is also accounted as critical. The popular perception about deterrence was that although related penalties and actions exist, it is not usually experienced in practice. Pressure was believed to be rarely existed, as government authorities do not frequently introduce changes.

3) Legal and political factors: The interviews were conducted before April 2021 when there were no taxes and interest rates introduced in Oman. They were not applicable and therefore were unimportant, as reflected in Table V. Even with their introduction an application, it is still a nominal concern for government driven organizations. On the other hand, laws and regulations and government interest were marked as critical as commonly commented as actively overseen in the participants' organization as key factors.

4) Economic factors: As primarily based on government funding, all participants concur that it is critical. As for the cost and budget, the majority believes that although cost is an important factor to invest in the efficacy of the CSS, it has not been a key problem for the public sector. These verdicts are also reflected in Table VI.

5) Technical factors: As reflected in Table VII, all participants strongly believed that the technical aspects of the CSS are of utmost importance. This perception is true mainly because a substantial part of the operations and processes are supported by IT-based systems in which the listed factors are inevitable. However, a few participants pointed out that change management is unless important. They remarked that the changes introduced are either infrequent or are easily manageable. This notion is also supported the perception about the pressure factor in the Cultural class.

6) Risk factors: The common consensus about the risk factors was that all of them are high importance as they all are necessary to be monitored, analyzed, and managed earnestly not just in the context of an effective CSS but, also with regards the sensitivity of the public information that they are dealing with. They also indicated to have a clear risk treatment plan and protocols that their organization follow. P2 stated that they don't have such plan and mechanism in place and that their organization tends to decide one when there is a need and that too for only severe and organizational wide risks. Table VIII highlights the scores associated with the risk factors.

Based on the interviews and the scaled defined, the list of critical factors are identified, as illustrated in Fig. 3.

TABLE II. PARTICIPANT PROFILE SUMMARY

Interviewee Code	Age	Qualification	Designation	Overall experience	Experience in security setting
P1	35	Bachelor	Security Analyst	5	5
P2	38	Master	Head of Data center	8	8
P3	38	Master	Senior Security Specialist	10	8
P4	31	Bachelor	Security Specialist	5	5
P5	30	Bachelor	Data Security Analyst	5	5
P6	37	Master	IT Deputy Manager	10	5
P7	34	Master	System Developer	7	5
P8	35	Bachelor	Head Security Operation Dept.	7	7
P9	36	Master	Network Deputy Manager	9	5
P10	45	Ph.D.	Associate professor	15	10

TABLE III. ORGANIZATIONAL FACTORS' LEVEL OF IMPORTANCE

Factor	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Average
IS Policy	5	5	5	5	5	5	5	5	5	5	5
Management Support	5	5	5	5	5	5	5	5	5	5	5
Skills & Expertise	5	5	5	5	5	5	5	5	5	5	5
Organization Structure	2	5	4	4	4	4	4	4	4	5	4
Organization Size	1	4	2	4	4	3	2	2	2	3	2.7
Strategy	5	4	5	5	5	5	5	5	5	5	4.9
Shared Values	4	1	4	4	4	4	4	4	4	4	3.7
Due Diligence	5	5	5	5	5	4	5	5	5	4	4.8
Risk Posture	1	5	5	5	5	2	4	4	4	4	3.9

TABLE IV. CULTURAL FACTORS' LEVEL OF IMPORTANCE

Factor	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Average
Attitude & Behavior	5	5	5	5	5	5	5	5	5	5	5
Pressure	1	4	2	4	5	2	3	3	3	4	3
Deterrence	1	4	4	4	4	4	4	4	4	4	3.7
Involvement	1	5	5	5	5	4	5	5	4	4	3.8
Awareness	5	5	5	5	5	5	5	5	5	5	5
Collaboration	4	4	5	5	5	5	5	5	5	4	4.7
Compliance	4	4	4	4	4	4	4	4	4	4	4

TABLE V. LEGAL/POLITICAL FACTORS' LEVEL OF IMPORTANCE

Factor	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Average
Cybercrime law	5	5	5	5	5	4	5	5	5	5	4.9
Government Interest	5	5	5	5	5	5	5	5	5	5	5
Taxes and Interest rates	1	1	1	1	1	1	1	1	1	1	1

TABLE VI. ECONOMIC FACTORS' LEVEL OF IMPORTANCE

Factor	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Average
Funding	5	5	5	5	5	5	5	5	5	5	5
Costs	1	4	1	4	4	3	4	4	2	5	3.2

TABLE VII. TECHNICAL FACTORS' LEVEL OF IMPORTANCE

Factor	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Average
Change Management	1	1	1	5	5	5	2	5	5	5	3.5
Application Security	5	5	5	5	5	5	5	5	5	5	5
Disaster Recovery Planning	5	5	5	5	5	5	5	5	5	5	5
Business continuity planning	5	5	5	5	5	5	5	5	5	5	5
Security Audit	4	4	5	5	5	4	5	5	5	4	4.6
Level of protection	5	5	5	5	5	5	5	5	5	5	5

TABLE VIII. RISK FACTORS' LEVEL OF IMPORTANCE

Factor	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	Average
Vulnerabilities	4	4	4	4	4	5	5	5	5	5	4.5
Threats & attacks	4	5	4	4	4	5	5	4	4	5	4.4
Threat actor	4	5	4	4	4	5	5	5	5	5	4.6
Risk Treatment	4	2	4	4	4	4	4	4	4	4	3.8

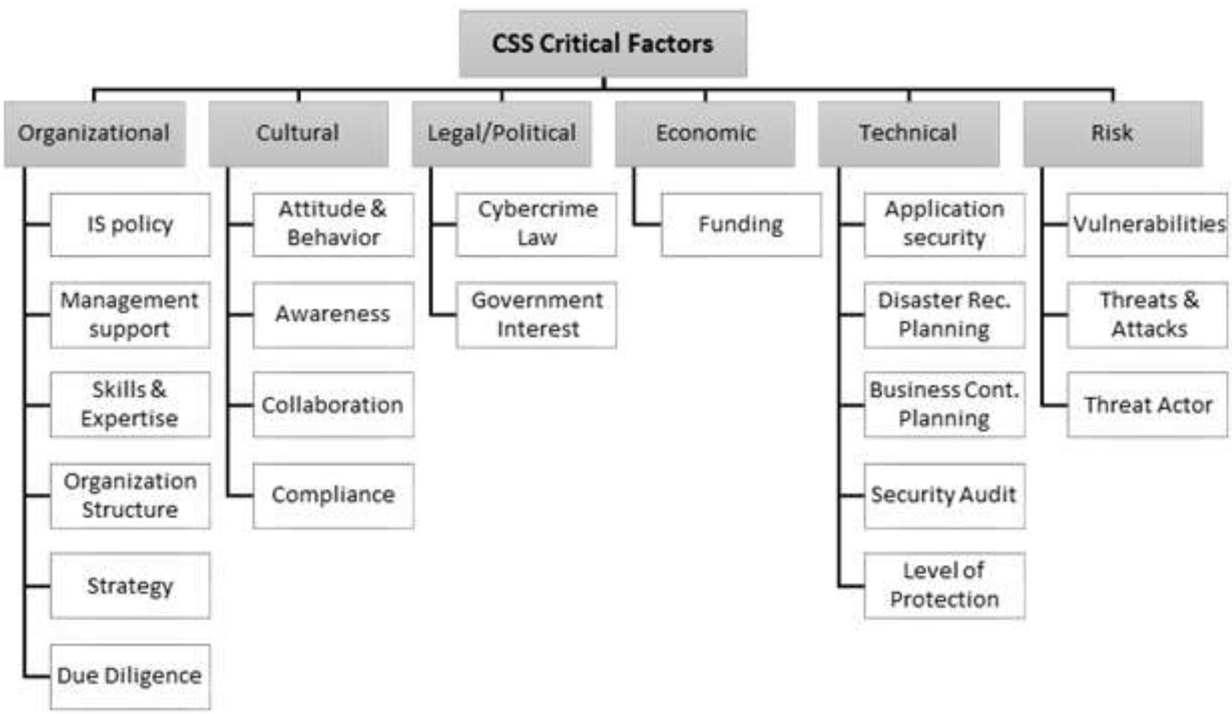

Fig. 3. List of Critical CSS Factors.

IV. COMPARISON

In this section, we provide a comparison of our classification with the studies summarized in Table I. However, we have selected only the 10 most relevant ones that cover the majority of the factors that are also common in the other attempts listed there. The comparison is provided in Table IX to XI. The tick mark indicates that a particular factor is stressed as an essential CSS factor whereas, the cross sign highlights that the given factor is not addressed essential. Overall, it can be concluded that our work provides a more complete list of factors rather than emphasizing a particular set of factors. Moreover, it can be observed that most of these works have mainly focused on the organizational and cultural aspects, whereas other key contexts of the business have been overlooked.

TABLE IX. COMPARISON OF ORGANIZATIONAL FACTORS

Work	Class (A) Organizational Factors								
	A.1	**A.2**	**A.3**	**A.4**	**A.5**	**A.6**	**A.7**	**A.8**	**A.9**
This work	✓	✓	✓	✓	✓	✓	✓	✓	✓
Jalali et al. [2]	×	×	×	×	×	×	×	×	×
Benson et al. [12]	×	×	×	×	×	✓	×	×	×
Fritzvold [13]	×	✓	×	×	×	×	×	×	×
Awan et al. [14]	×	×	×	×	×	×	×	×	×
Glaspie et al.[15]	✓	✓	×	×	×	×	×	×	×
Khansa et al. [16]	×	×	×	×	×	×	×	×	×
Ebenezer [19]	×	×	×	×	×	×	×	×	×
Cooke. [20]	×	×	✓	×	×	✓	×	×	×
Choejey et al. [21]	✓	×	×	✓	×	×	×	✓	×
Peursm [22]	×	×	✓	✓	×	✓	✓	×	×

TABLE X. COMPARISON OF CULTURAL, LEGAL/POLITICAL AND ECONOMIC FACTORS

Work	Class (A) Organizational Factors							Class (C) Legal/Political Factors			Class (D) Economic Factors	
	B.1	**B.2**	**B.3**	**B.4**	**B.5**	**B.6**	**B.7**	**C.1**	**C.2**	**C.3**	**D.1**	**D.2**
This work	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Jalali et al. [2]	×	×	×	×	×	×	×	×	×	×	×	×
Benson et al. [12]	✓	×	×	×	✓	×	×	×	×	×	×	×
Fritzvold [13]	×	×	×	×	✓	×	✓	×	×	×	×	×
Awan et al. [14]	×	×	×	×	×	×	×	×	✓	×	×	×
Glaspie et al.[15]	✓	×	✓	✓	✓	×	×	×	×	×	×	×
Khansa et al. [16]	✓	×	✓	✓	✓	×	×	×	×	×	×	×
Ebenezer [19]	×	×	×	×	×	×	×	×	×	×	×	×
Cooke. [20]	×	×	×	✓	✓	×	×	✓	×	×	✓	×
Choejey et al. [21]	×	×	×	×	✓	×	×	×	×	×	✓	×
Peursm [22]	×	×	×	×	×	×	×	×	×	×	×	×

TABLE XI. COMPARISON OF TECHNICAL AND RISK FACTORS

Work	Class (E) Technical Factors						Class (F) Risk Factors			
	E.1	**E.2**	**E.3**	**E.4**	**E.5**	**E.6**	**F.1**	**F.2**	**F.3**	**F4**
This work	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Jalali et al. [2]	×	✓	✓	✓	×	×	×	×	×	×
Benson et al. [12]	×	×	×	×	×	×	×	×	×	×
Fritzvold [13]	×	×	×	×	×	×	×	×	×	×
Awan et al. [14]	×	×	×	×	×	✓	×	×	×	×
Glaspie et al.[15]	×	×	×	×	×	×	×	×	×	×
Khansa et al. [16]	×	×	×	×	×	×	×	×	×	×
Ebenezer [19]	×	×	×	×	×	×	×	✓	✓	×
Cooke. [20]	×	×	×	×	×	×	×	×	×	×
Choejey et al. [21]	✓	×	×	✓	✓	×	×	×	×	×
Peursm [22]	×	×	×	×	×	×	×	×	×	×

V. Conclusion

To develop and implement an effective CSS, we need to recognize and evaluate the necessary factors that might influence its efficacy. In this article, we have accumulated a comprehensive list of such essential factors in accordance with the critical areas of an organization that are vital to be recognized and evaluated for any long-term planning, such as developing a CSS. The comparison depicts that the proposed classification covers and provides a broader view of the essential CSS Factors as compared to the current attempts that emphasize on a specific domain or context of a business. Such a holistic classification of essential factors can provide a fundamental ground for organizations planning to develop and implement a CSS to understand and evaluate the influencing aspects of it and to plan accordingly. Furthermore, we have also listed the critical factors in the public sector in Oman. However, we believe that this study is limited in scope and that the corresponding critical factors assessed may vary considerably in regions or spaces with different legal, political, economic, and cultural backgrounds. More data need to be collected and analyzed to conclude whether this list of critical factors will shrink or grow, and it will be interesting to see how different types or organizations in a broader geospatial context comprehend the criticality of the different factors. In future, we plan to further refine the classification proposed and conduct a wider data collection approach to evaluate the critical factors.

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Automatic Speech Recognition Features Extraction Techniques: A Multi-criteria Comparison

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***Abstract*—Features extraction is an important step in Automatic Speech Recognition, which consists of determining the audio signal components that are useful for identifying linguistic content while removing background noise and irrelevant information. The main objective of features extraction is to identify the discriminative and robust features in the acoustic data. The derived feature vector should possess the characteristics of low dimensionality, long-time stability, non-sensitivity to noise, and no correlation with other features, which makes the application of a robust feature extraction technique a significant challenge for Automatic Speech Recognition. Many comparative studies have been carried out to compare different speech recognition feature extraction techniques, but none of them have evaluated the criteria to be considered when applying a feature extraction technique. The objective of this work is to answer some of the questions that may arise when considering which feature extraction techniques to apply, through a multi-criteria comparison of different features extraction techniques using the Weighted Scoring Method.**

Keywords*—*Automatic speech recognition; feature extraction; comparative study; MFCC; PCA; LPC; DWT; WSM

I. Introduction

Features extraction is a fundamental step in the Automatic Speech Recognition (ASR) process, in which relevant data are extracted from a speech. After pre-processing a speech signal (noise reduction, endpoint identification, pre-emphasis, framing, and normalization), the feature extraction stage retains a set of predefined features from the processed speech, using extraction techniques such as Mel-Frequency Cepstral Coefficients (MFCCs), Discrete Wavelet Transforms (DWTs), Linear Predictive Coding (LPC) and other techniques that will be explored in greater depth in this paper focusing on the advantages and disadvantages of each one.

The content of this paper is structured as follows. In Section 2 we review related work that has been done to compare existing features extraction techniques. In Section 3 we describe the different features extraction techniques. Then, in Section 4, we present the main advantages and disadvantages of each extraction method. In Section 5 we provide a multi-criteria comparison of the different methods based on the Weighted Scoring Method (WSM). Finally, we end with a conclusion.

II. Related Work

Several works have been conducted to compare ASR features extraction techniques [1][2][3][4][5][6]. Most of this research has been focused on the advantages and disadvantages of each extraction method. Nevertheless, it is relevant to illustrate the importance of each one depending on the criteria that represent the key elements when deciding on which method to use for feature extraction in a speech recognition system.

In the research [3] most commonly used feature extraction techniques have been discussed, like LPC, MFCC, Zero Crossings With Peak Amplitudes (ZCPA), DTW, and Relative Spectral Processing (RASTA). In this work, the limitations of each the advantage of each technique have been addressed. Also, it was mentioned that most research used only a single feature extraction technique and that is important to think about using hybrid techniques that combine between two or more than one feature extraction technique. In the same scope, another research [4] has been established a comparison of various feature extraction techniques (MFCC, LPC, DWT, PLP…) considering the specific advantages and the shortcomings of each.

An analysis of different feature extraction techniques has been investigated in the work [5], for isolated words speech in a clean and noisy environment for feature extraction techniques like PLP, RASTA PLP, LPCC, and MFCC. This analysis has been based on a comparison of the obtained accuracy, using each technique in both noisy and clean environments. Another work [6] has studied the performance of commonly used feature extraction techniques (MFCC, LPC, and PLP) for speech recognition. Through illustrating their benefits and drawbacks. This paper highlights the importance of hybrid feature extraction techniques to benefit from the advantage of multiple techniques at the same time.

III. Speech Features Extraction Techniques

The features extraction methods are used to remove irrelevant information from a speech signal. Depending on the type of feature to be extracted, feature extraction methods can be classified into two main categories: Spectral feature analysis methods, which use the spectral representation of the speech signal. And temporal feature analysis methods, which use the original form of a signal.

The well-known feature extraction method in the field of ASR is the Mel-frequency cepstral coefficient (MFCC). In addition to this technique, there are other extraction methods for ASR, such as the Discrete wavelet transform (DWT), Wavelet packet transforms (WPT), Relative Spectral-Perceptual Linear Prediction (RASTA-PLP), Linear predictive coding (LPC), and others. We present in-depth each of these methods in the following sections.

A. Spectral Feature Analysis Methods

1) Mel-Frequency Cepstral Coefficients (MFCC): Several researchers chose MFCC as their feature extraction method. Since the mid-1980s, MFCCs are the most widely used feature extraction method in the field of ASR. Most of the works concerning Moroccan Darija Speech recognition have used the MFCC as a feature extraction method [7], [8]. The main purpose of this feature extraction method is to mimic the human ear. The MFCC is calculated by first splitting the speech signal into alternating frames with a length of 25 or 30 milliseconds and a 10-millisecond overlap between consecutive frames. The discrete Fourier transform (DFT) is computed on each windowed frame after each frame is multiplied with a Hamming window function.

MFCC is well-known and commonly used in the field of speech recognition, but they do have some drawbacks. The key disadvantage of MFCC is its poor robustness to noise signals, as noise signals change all MFCCs if at least one frequency band is skewed. Various normalization techniques are used for enhancing the robustness of MFCC to noise-corrupted speech signals, in both training and testing conditions. These include features statistics normalization techniques such as mean and variance normalization (MVN), histogram equalization (HEQ), and cepstral mean normalization (CMN). Another important issue with MFCCs is that these are derived only from the power spectrum of a speech signal, ignoring the spectrum phase. However, the provided information by this phase is also useful for speech perception. This problem is tackled by performing speech enhancement before starting features extraction.

2) Principal Component Analysis (PCA): Determining a linear combination that can be used to represent the original speech signal is the main role of PCA in the feature extraction stage. PCA is mainly used for dimensionality reduction and features de-correlation. It is the most used method to increase the robustness of the speech recognition systems in a noisy environment. The research presented in [9], states that the PCA analysis is required when the speech signal is corrupted by noises. Another research confirms that the usage of PCA had given further reduction in the error rates [10]. In the research [11] the combination of PCA with MFCC had increased the recognition rates obtained with noisy speech signals from 63.9% to 75.0%. However, less accuracy is obtained using PCA for spontaneous and continuous speech recognition [12].

3) Linear Predictive Coding (LPC): The LPC is the most important method for extracting features [13] and the most used in several works [14][15]. Unlike MFCC, this method imitates the basic structure of a vocal tract when a sound is produced. LPC analysis is carried out by generating frames for the input speech signal, then performing windowing on each frame to reduce the discontinuities at the beginning or the end of a frame. Finally, the inter-frame autocorrelation is calculated. LPC method recognition quality is affected by noises, several works proposed new approaches to enhance the performance of this method in a noisy environment [16]. Multiple works have used LPC in combination with DWT [17], by using DWT to decompose the input speech signal and LPC to model each sub-band. The results obtained confirm that this method outperforms by 10% the MFCC method.

4) Linear Predictive Cepstral Coefficient (LPCC): The LPCC is considered as an extension of the LPC method [8]. After performing the LPC analysis, cepstral analysis is carried out to obtain the corresponding cepstral coefficient. Many researchers studied the performance of both LPCC and MFCC. The results obtained in [18] show that MFCC and LPCC share the same results. Another research [19] compared the two methods confirm that LPCC was 5.5% faster and 10% more efficient than MFCC.

5) Perceptual Linear Prediction (PLP): The PLP method is mainly used to remove unwanted information from a speech signal and improves the speech recognition rate. The PLP analysis consists of two important stages. First by approaching the auditory system spectrum by the model of all poles, then calculating the auditory spectrum [20]. The results of PLP analysis and LPC are identical, with the exception that the order of the PLP analysis model is half of the LPC model. This model allows for storage saving of automatic speech recognition storage and also provides good ASR performance.

B. Temporal Feature Analysis Methods

1) Discrete Wavelet Transforms (DWT): In addition to the frequency information, the temporal information in speech signals is also important for speech recognition applications [21][22]. Due to the non-stationary nature of speech signals, DWT obtains temporal information by re-scaling, shifting, and analyzing the mother wavelet. In this manner, the input speech signal is analyzed at various frequencies and resolutions. Since a speech signal is analyzed at decreasing frequency resolution for increasing frequencies, the DWT provides an appropriate model for the human auditory system and it was used in various researches at the feature extraction stage [23][24]. In comparison to MFCC, the DWT offers better frequency resolution at lower frequencies. As previously mentioned, MFCC is not robust for noise-corrupted speech signals. Because of their ability to provide localized time and frequency information, DWT was effectively used for de-noising tasks.

Several researchers considered combining the DWT and the MFCC to gain the benefits of both methods. This combination is known as Mel-Frequency Discrete Wavelet Coefficients (MFDWC) and is produced by applying the DWT to the Mel-Scaled log filter bank energies of a speech frame. In the works [25][26] the MFDWC method was used and for both clean and noisy environments, the results showed that MFDWC achieved higher accuracy as compared to MFCC and wavelet transforms alone.

2) Wavelet Packet Transforms (WPT): The wavelet packet transform is an extension of the standard wavelet decomposition that provides extra signal processing options. When compared to the wavelet transform, it better represents high-frequency information. The main difference between wavelet transforms and wavelet packet transform is that the latter split details as well as approximations.

WPTs are similar to DWTs, except that both the approximation and detail coefficients are more decomposed. The research [1] compared WPT's performance to that of DWT for the task of ASR, the results showed that WPT-based methods performed better as than WPT's.

3) Relative Spectra–Perceptual Linear Prediction (RASTA-PLP): The RASTA–PLP analysis involves combining the RASTA technique with the PLP method to improve the robustness of the PLP features. This method is based on the fact that the temporal properties of a speech signal environment differ from those of the speech signal. Thus, by using band-pass filtering on each frequency sub-band of a speech signal, the effects of channel mismatch between the training and testing environments are reduced and the short-term noises are smoothed [27]. The work done in [28] confirms the robustness of RASTA–PLP for noisy environments. Another work [29] have compared the RASTA–PLP with LPC and MFCC feature extractions techniques, the obtained results shown That the RASTA–PLP performs better than MFCC and LPC for noisy speech signal with an accuracy of 73% while 60% accuracy had been obtained using MFCC and 53% of accuracy obtained using LPC. Furthermore, RASTA-PLP performs much better when it is combined with the WPT method.

IV. Comparison of Feature Extraction Techniques

There are several criteria to consider when chosen a feature extraction technique, such as the accuracy of recognition in a noisy speech environment, computations costs, storage space, temporal information of speech signals, and others.

When it comes to noisy environments RASTA–PLP outperforms MFCC, PLP, and LPC features extractions methods. The MFCC is suitable for a clean speech and performs better for an isolated speech environment, while it is low robust to noise and not suitable for a continuous speech environment since the MFCC frame may contain information of more than one phoneme. For more robustness either MFCC, LPC or PLP may be combined with other feature techniques such as DWT or WPT for enhancing systems robustness when it is needed to use such feature extraction techniques in a noisy environment [30]. The temporal information of a speech signal is as significant as its frequency information. The DWT and WPT outperform the well-known MFCC for such issues. Thanks to these two methods a better accuracy is achieved for phonemes recognition. Also, available memory space is an important criterion for choosing the feature extraction method that will achieve good accuracy with a limited feature vector size. DWT may be a good option when only small storage is available. While MFCC requires more storage space. For this reason most of the time, MFCC is used in combination with other features extraction techniques to reduce the dimensionality of extracted features and to obtain good accuracy, vector quantization (VQ), PCA, or LDA [31][32].

The profits and constraints of the above discussed features extraction techniques are illustrated in Table I.

TABLE I. Features Extraction Techniques Comparison

Feature extraction	Pros	Cons
MFCC	- High recognition accuracy [27] - Good discrimination and low coefficients correlation [27]	- Inaccurate recognition in noisy speech [27] -high dimensional features vectors [31]
PCA	- Robustness to noises [9] - Reduce the feature vector's size while retaining important information [15]	- Expensive in terms of computing for high-dimensional data [27]
LPC	- Computation speed - Robust for extracting features from speech signals with a low bit rate [33]	- Highly correlated feature coefficients [27] - Unable to distinguish words with similar phonemes
LPCC	- Decorrelate feature coefficients by the cepstral analysis - Robust than LPC [27]	- Unable to analyze local events accurately
PLP	- Low-dimensional feature vector [27] - Reduce the gap between voiced and unvoiced speech	- Altered Spectral balance [27]
DWT	- Denoising speech signal [34] - Compressing speech signal without significant loss of its quality [27]	- Inflexible [27]
RASTA–PLP	- Robustness - Excludes variations between cepstral components and speech signal [27]	- Low performance for noiseless speech [21]

V. Multi-criteria Comparison

After describing the advantages and disadvantages of each feature extraction method in this section we present a multi-criteria comparison of these methods. In this comparison, we used the Weighted Scoring Method (WSM), which is known as the simple additive weighting method, which involves adding up the criteria values for each alternative and applying the individual criteria weights [35]. To apply this method, we went through the steps below:

- Criteria selection.
- Assigning weights to criteria based on their importance.
- Creating a matrix containing weights for each criterion.
- Calculation of weights scores.

A. Comparison Criteria

The choice of comparison criteria was based on the common characteristic shared between previously cited feature extraction methods. In the following we present the most important criteria to be considered when choosing a speech feature extraction technique:

- C1=Robustness to noises: This criterion involves if we can use a feature extraction technique when a speech signal is corrupted by noises.
- C2=Memory storage: This criterion concerns the size of storage space required for the spectral analysis of a speech while maintaining important information from a speech.
- C3=Dimensionality reduction: This criterion indicates the ability of a feature extraction technique to reduce the dimensionality of extracted features while obtaining a good accuracy.
- C4=Computational Complexity: This criterion covers the computational costs of a feature extraction method in terms of time and speed.
- C5=Computational Speed: This criterion covers the computational costs of a feature extraction method in terms of time and speed.
- C6=Temporal information within speech: This criterion highlights the implication of temporary information of a speech by the feature extraction method.
- C7=Suitability for continuous speech: This criterion considers the performance of a feature extraction method in the context of a continuous speech.
- C8=Suitability for spontaneous speech: This criterion considers the performance of a feature extraction method in the context of a spontaneous or a real-time speech.
- C9=Suitability for isolated words speech: This criterion points out the performance of feature extraction when dealing with isolated words speech.
- C10=Reinforcing recognition rate: This criterion indicates whether the application of a feature extraction method improves the speech recognition rate.

B. Application of WSM

The application of the WSM method consists of determining the multi-criteria matrix where the columns represent the feature extraction methods and the rows represent the criteria with their corresponding weights. The score attributed to each criterion has been induced from the comparison detailed in the previous sections.

The scoring is based on five levels where each one is defined as follows:

- Score "1": A poor nor lower performance is obtained using a method.
- Score "2": Inflexibility and lack of efficiency using a method.
- Score "3": A good option, but there are some limitations to use a method.
- Score "4": Significant results are obtained, more flexibility for foreign contexts is needed.
- Score "5": Approved efficiency, all requirements are met by using a method.

In Table II, the resulting WSM Matrix is presented according to the score assigned to each criterion.

TABLE II. WSM Matrix

	MFCC	**PCA**	**LPC**	**LPCC**	**PLP**	**DWT**	**RASTA–PLP**
C1	1	5	1	1	4	5	5
C2	2	4	3	3	5	4	5
C3	2	5	4	4	5	5	4
C4	5	2	3	4	4	2	4
C5	3	4	5	5	4	4	5
C6	3	4	1	1	3	5	3
C7	2	3	2	3	4	4	4
C8	2	2	2	3	3	3	4
C9	5	4	4	4	4	2	3
C10	4	5	3	4	4	5	5

VI. Discussion

According to the multi-criteria comparison of different feature extraction techniques, each feature extraction technique performs better for a particular criterion, as shown in the WSM results in Matrix presented in Table III, we can see that MFCC is less complex and effective for extracting features from an isolated words speech, but it lacks robustness to noises, which make it non preferred for other speech types (spontaneous, continuous).

TABLE III. WSM RESULTS

	Weights	MFCC	PCA	LPC	LPCC	PLP	DWT	RASTA–PLP
C1	10	10	50	10	10	40	50	50
C2	10	20	40	30	30	50	40	50
C3	10	20	50	40	40	50	50	40
C4	10	50	20	30	40	40	20	40
C5	15	45	60	75	75	60	60	75
C6	5	15	20	5	5	15	25	15
C7	10	20	30	20	30	40	40	40
C8	5	10	10	10	15	15	15	20
C9	15	75	60	60	60	60	30	45
C10	10	40	50	30	40	40	50	50
Scores	100	305	390	310	345	410	380	425

Other extraction methods like PCA, DWT, and RASTA-PLP are effective in reducing noise, which is an important factor in building a robust ASR system. Temporal information within a speech is less considered by most feature extraction methods. Also, memory storage optimization is an important issue to be filled by a feature extraction method.

From these results, we can deduce that none of the presented methods meet the flexibility and robustness requirements of ASR. The multi-criteria spider graph shown in Fig. 1 illustrates that there is no complete extraction method that respond to each criterion. However, we emphasize the importance of combining multiple feature extraction techniques to benefit from the effectiveness of each.

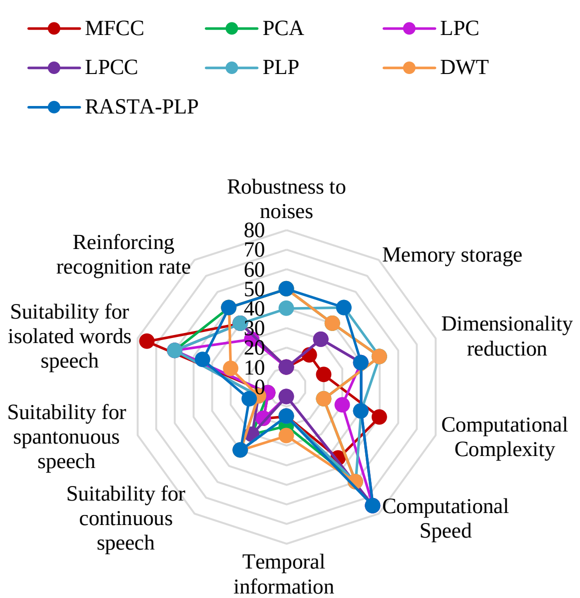

Fig. 1. Multi-criteria Spider Chart.

VII. CONCLUSION

In this work, we presented a multi-criteria comparison of commonly used feature extraction techniques in ASR. The choice of feature extraction techniques is a crucial step in the speech recognition process since the wisely we choose the extraction technique, the more accurate results we get.

This comparison revealed that each extraction method has reliability and performance issues. Also, the results showed the importance of applying hybrid feature extraction techniques since each of the presented extraction techniques complements the work of another.

The main objective of this multi-criteria comparison is to help researchers to select the feature extraction method according to the criteria that matter most for speech recognition.

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An Approach for Requirements Engineering Analysis using Conceptual Mapping in Healthcare Domain

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***Abstract*—Healthcare systems aim to achieve the best possible support for patient care and to provide good medical care. Good analysis of requirements is essential to avoid any crises. Elicitation of healthcare systems requirements is an emerging and critical phase. It is a challenging task to deal with constraints from the stakeholders and restrictions of the legal issues. In this research, an approach "Conceptual Mapping for non-functional Health care Requirements; CMHR" is proposed to perform an analysis and to evaluate the relationship between the clinical non-functional requirements of medical devices (ventilators as an example in this research) according to the following five attributes: prioritization of requirements, suitability, feasibility, achievability, and risky. Requirements are automatically clustered using the K-means++ algorithm to find out the optimal number of clusters. Requirements are then clustered to visualize the concept map. Clustering is applied on different combinations of the attributes to sort the requirements and to visualize them. Label names are assigned to the classes of requirements to assign each requirement to the appropriate class. Consequently, a prediction of a new requirement can be figured automatically. The approach achieved less rework, fast delivery of the project with good quality, and achieved a higher level of user satisfaction.**

Keywords—Conceptual mapping; healthcare systems; clustering; requirement engineering analysis

I. Introduction

Healthcare systems aim to achieve the best possible support for patient care and to provide good medical care. software engineering is an emerging field for healthcare systems. Clinical requirements are more complex comparing to other types of requirements as they should be in specific terms. Software requirement engineers should concentrate when eliciting requirements to avoid making mistakes that could be disastrous in healthcare [1]. Software Requirement analysis; also known as software requirement engineering, aims to ensure that systems meet the needs of stakeholders while also determining user expectations. Requirement analysis consists of activities that are important to the software development process [2]. This process is composed of the following activities [2]: elicitation, modeling and analysis, assurance, management, and Evolution. First, the elicitation phase is called software requirements elicitation, which is a challenging task to understand and analyze software requirements specifications. Its objective is discovering stakeholders' needs, and understand the context [2]. It's important to perform this step carefully, to minimize the changes that may occur in order to save software development time [3]. Second, requirements analysis and negotiation; requirements are identified, and system modeling is performed. Third, requirement specification while the requirement should be documented in a format of Software Requirements. Fourth, validate the requirements to ensure that requirements meet the needs of the stakeholders. Finally, Requirements management is the last activity to manage all requirements-related activities [4] [5]. Further, the requirements are written in natural text format, requirements should be thoroughly analyzed to generate the software requirements specifications needed to validate and verify the final product. Software requirements are divided into Functional and non-Functional requirements [6]. Functional requirements are about the software service and its functional behavior, while non-functional requirements focus on the performance and the quality of requirements that are unrelated to software functionality [7].

The healthcare system is an emerging field. Projects should be well analyzed to avoid any crises. The consequences of poor requirement analysis lead to project failure, consuming effort and time, and repeating tasks and processes. In this research, an approach is presented to analyze non-functional requirements through the use of unsupervised learning to arrange the related requirements into clusters. This approach visualizes and sorts the nonfunctional requirements through conceptual mapping. Furthermore, the approach can predict the class of the new requirements.

The rest of this paper is organized as follows: Section 2 explains the background of some related concepts, Section 3 illustrates the literature review, Section 4 discusses the proposed methodology, and finally Section 5 explains the experimental results.

II. Background

Machine learning consists of three different types, which are supervised learning, unsupervised learning, and reinforcement learning [8]. In this research, the k-means clustering method is used to group similar data into one group. The related data is combined to make it easier to find relationships between data.

The requirement engineering consists of a series of activities, [4] that begin with requirement elicitation and inception to meet the needs and desires of the stakeholders. Then requirements analysis and negotiation; requirements are identified, and system modeling is performed, which necessitates that the product is completely modeled and designed prior to the construction. Then requirement specification; requirement should be documented in a format of SRS. While the validation of the requirements to ensure that they meet the needs of the stakeholders is the next activity. Finally, Requirements management is the last activity to manage all requirements-related activities. [5].

Conceptual mapping is a diagram that visualizes the semantic relations between concepts [9]. Conceptual maps help to give a consistent evaluation. This process mainly composed of the following steps; first, make brainstorming then generate the statement of needs, after that sorting and rating these statements, then represent the statements on the map that's could be called as conceptual mapping analysis. Finally, they make interpretation for the map and utilize it [10][11]. Conceptual mapping creates a structure of clustered concepts and provides a visual or graphical representation of data.

III. Literature Review

Al-Dahmash et al. in [12], proposed SEMHTA, a methodology for healthcare to build system and application with reliable and protected software. It stands for software engineering methodology for healthcare applications development, this methodology relies on what developers do when building a different system. There was no consideration for the elicitation phase. Gausepohl et al. in [13], proposed a methodology in a healthcare system that focused on storytelling in the elicitation phase for medical device requirements. Results contributed similar quantity and breadth of information in significantly less time. Participants contributed more distinct context-of-use information with an emphasis on the social context using ontology technics. However, this methodology presents the elicitation of medical device requirements rather than a clinical requirement. Kaiya et. al. [14] did similar work to enhance requirement elicitation using ontology technical web mining and lightweight natural language processing, but this wasn't applied with healthcare systems. Widya et al. in [15], proposed a methodology for eliciting requirements in the eHealth domain. Developers developed a scenario that reflects the treatment protocol and it works with telemedicine treatment. Martin et al. in [16], proposed a user center designed approach in the clinical systems to keep users in the cycle of development. They performed semi-structured open-ended interviews to investigate the clinical need for the device as well as the supposed effects for patients and clinical users. Regarding approaches in requirements engineering in the non-clinical systems: Laporti et al. in [17], proposed the Athena approach that applied requirements elicitation by grouping storytelling from users to be merged in one story. Stories then transformed to scenarios then to use-cases. Andreas et al. in [18] explore and define a requirement engineering methodology for machine learning systems. This methodology incorporates additional types of standards, such as special legal requirements, and explains the ability and freedom from prejudice, in order to enhance the requirement engineering process. They improve the machine learning models by taking too many decisions. Kamal Rudin et al. [19] [20] have created a simple method for gathering consistent requirements from the client stakeholders. A library pattern that supports various application domains is developed to store the essential requirements following the essential use-case. The library pattern, on the other hand, is not concerned with the use of healthcare requirements. Hamzeh Eyal Salman in [21], designed an approach to cluster functional requirements automatically based on semantic measure Using Agglomerative Hierarchical Clustering (AHC) by grouping similar functional requirements into clusters. Results achieved high performance according to a well-known measure and didn't apply yet for the clinical system. Zeng Zhen in [22], applied the TA-ART algorithm ta generate an automatic concept map for text, by making text analysis and set records into clusters. Nadiah Daud in [23] created a methodology to enhance requirements elicitation. This methodology is composed of three phases; 1) the analysis: they collect requirements to analyze it or read the literature and gather requirements to analyze gaps and requirements. 2) they go to the design and development. 3) they make an evaluation and test the results. Rebecca Orsi in [10] presented a study using concept maps analysis by running more than multiple cluster analyses to describe a quantitative validity analysis. She used the R statistical software methods and packages to represent four clustering methods.

IV. Proposed Approach

This research presents a novel approach; "Conceptual mapping for health care non-functional requirements, (CMHR)". This approach is applied to requirement engineering to enhance the analysis process of the requirements. CMHR is composed of three phases as illustrated in Fig. 1. The first phase is Requirements Gathering. In this phase, the non-functional requirements are extracted from the software requirements specifications. The domain experts rank requirements by the identified attributes (suitability, priority, stability, risky, achievable) from 1 to 5. The second phase is Data Preprocessing. In this phase, the data pass through preprocessing phase to prepare the data for the next step and to ensure that the data is cleaned. The third phase is Machine Learning and visualization. In this phase, the approach starts to perform clustering using the k-means++ algorithm to perform the conceptual mapping analysis. In this phase, The Elbow method is used to calculate the number of clusters, then clustering the related requirements to each other based on similarity according to the identified attributes. Then, a visualization is performed through a matplotlib plot, and the data is exported to CSV file. Now labeling of the clusters and requirements can be performed. The benefit of labeling the data is to make a classification for the requirements and split it into the training and testing set. Finally, predict the new requirements classification. The details of these phases are decelerating in the following diagram.

Phase 1: Requirements Gathering. This phase consists of two main steps. Step1: Extract non-functional requirements from SRS. The structured requirements are extracted and the non-functional requirements are being selected to analyze it. In this research, 104 non-functional requirements are collected from SCRIBD1 website about ventilators as a medical device. Table I illustrates a sample of these requirements.

[1] https://www.scribd.com/document/467320184/10053865Q00-PB560-Ventilator-Power-Pack-Essential-Requirements-Matrix-pdf

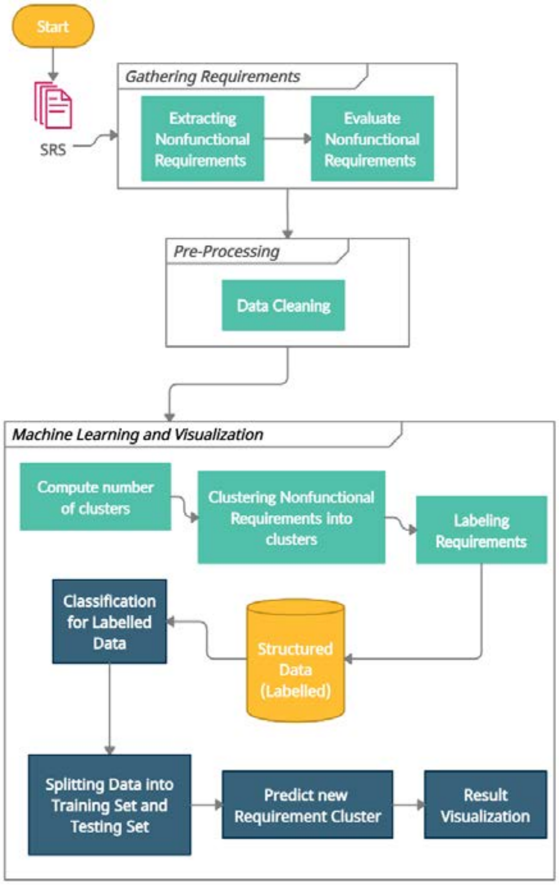

Fig. 1. Conceptual Mapping for Health Care non-Functional Requirements: CMHR.

TABLE I. A SAMPLE OF NON-FUNCTIONAL REQUIREMENTS FOR VENTILATORS DATASET

12.1 For devices which incorporate software or which are medical software in themselves, the software must be validated according to the state of the art taking into account the principles of development lifecycle, risk management, validation and verification.
12.2. Devices where the safety of the patients depends on an internal power supply must be equipped with a means of determining the state of the power supply.
12.3. Devices where the safety of the patients depends on an external power supply must include an alarm system to signal any power failure.
12.4. Devices intended to monitor one or more clinical parameters of a patient must be equipped with appropriate alarm systems to alert the user of situations which could lead to death or severe deterioration of the patient's state of health.
12.5. Devices must be designed and manufactured in such a way as to minimize the risks of creating electromagnetic fields which could impair the operation of other devices or equipment in the usual environment.
12.6. Devices must be designed and manufactured in such a way as to avoid, as far as possible, the risk of accidental electric shocks during normal use and in single fault condition, provided the devices are installed correctly.
12.7.1. Devices must be designed and manufactured in such a way as to protect the patient and user against mechanical risks connected with, for example, resistance, stability and moving parts.
12.7.2. Devices must be designed and manufactured in such a way as to reduce to the lowest possible level the risks arising from vibration generated by the devices, taking account of technical progress and of the means available for limiting vibrations, particularly at source, unless the vibrations are part of the specified performance.

Step 2: Requirements Evaluation. In this step, a group of qualified scientists evaluates the non-functional requirements from the SRS document with attributes. The selected attributes are suitability, priority, stability, risky, achievable. Then the following questions are asked about every single requirement to a domain expert.

- Suitability: How much this requirement is complete, correct, and appropriate?
- Priority: How much this requirement is important?
- Stability: Does the requirement has reached a certain level of stability?
- Risk: What's at stake if the requirement isn't implemented?
- Achievable: How far this requirement could be achieved?

The mean of the answers of the survey is taken and be considered during analysis.

Phase 2: Pre-processing. Data cleaning is the process; which implemented at this phase. The kernel-based random method is used. This method finds the relations between concepts or data to perform data cleaning and normalization [24]. Data cleaning detects errors, expels mistakes and irregularities from information in arrange to progress the quality of information [25]. So, this step, try to fill the missing data by setting the most relevant value by calculating the mean value using machine learning.

Phase 3: Machine Learning and Visualization. This phase consists of four main steps. Step1: Compute the number of clusters using the ELBOW method to determine the optimal number of clusters for the data. It uses the k-means++ algorithm and applies a range of values for the k from 1 to 10 on the dataset to calculate the WCSS. WCSS stands for the Within-Cluster-Sum-of-Squares. It's the sum of squares of the distance of each data in all clusters to their centroid point using the following formula:

$$WCSS = \sum_{C_k}^{C_n} \left(\sum_{d_i \, in \, C_i}^{d_m} distance(d_i, C_k)^2 \right)$$

Where,

C is the cluster centroids. And d is the data point in each Cluster. (1)

Step 2: Clustering similar Non-Functional Requirement: The k-means++ algorithm used to present multidimensional scaling by measuring similarity, which can be defined as the distance between various datasets; calculating the sum of the distance between point and centroid point. After calculating the distance, the group of related clusters is combined then the requirements could be visualized among the selected attributes throw the multidimensional scaling of the conceptual map and can be exported through CSV file. Requirements could be dynamically sorted based on any two selected attributes. Also, the map could fit for three attributes is developed.

Step 3: Labeling Requirements: Data labeling is the method of identifying the raw data. Data here is ready to be labeled after performing clustering; each requirement can be assigned with a label name. Assume there are four clusters, so a label will be assigned to each cluster based on the data in that cluster.

Step 4: Classification of labeled data: Data now in the shape of multi-label classes. Since the requirements are labeled in the last step, so the data is ready to be classified. The Naïve Bayes technique is applied in this research to make a classification for the labeled data. Naïve Bayes split the data into a training set and testing set in aim to learn the machine.

Step 5: Predicting the new requirement cluster: This is the final step. The developed approach can predict the classification of new requirements or for an edit of an existed requirement.

V. Experimental Study and Evaluation

The CMHR approach is applied to non-functional requirements of a ventilator device. First, 104 requirements were extracted from the SRS. Then the domain experts evaluated each requirement based on the defined attributes as it was explained in the previous section. The mean average of the evaluation was calculated and assigned to each requirement. Then the file is converted into CSV file. A sample of the data is presented in Table II.

The second step performs the preprocessing phase by using the sklearn library in python to complete the missing data. The data is ready now to perform the machine learning phase. This phase starts with computing the number of clusters using the ELBOW method to determine the optimal number of clusters, as shown in Fig. 2.

Fig. 2 depicts the result of the Elbow method. The clustering is applied based on prioritization and suitability. And figure showed the result of the optimal clusters is five.

Fig. 3 depicts the result of the Elbow method. Prioritization and achievability are used to cluster the requirements. The figure showed that the optimal clusters is four.

The next step is to cluster similar non-functional requirements using the k-means++ algorithm. The multidimensional scaling of the requirements is presented in Fig. 4 and Fig. 5.

In Fig. 4, Requirements are sorted and visualized based on prioritization and suitability attributes. Requirements are clustered into the five clusters as the Elbow method showed.

In Fig. 5, Requirements are sorted and visualized based on prioritization and achievability attributes. Requirements are clustered into four clusters as the Elbow method showed.

CMHR approach is implemented dynamically. It offers clustering the requirements based on three attributes and makes a 3-Dimensions representation. For example, Assum the clustering is made based on three attributes prioritization, suitability, and achievability.

Fig. 6 presents the result of the Elbow method. The clustering is applied based on prioritization, achievability and suitability. The figure showed that the optimal clusters is five.

Going through the next step to cluster similar non-functional requirements, the multidimensional scaling of the requirements is presented using the k-means++ algorithm in Fig. 7.

TABLE II. Ranking of Non-functional Requirements for Ventilators (Sample of the CSV File)

Requirements	**Suitable**	**Priority**	**Achievable**	**Feasible**	**Risky**
For devices which incorporate software or which are medical software in themselves, the software must be validated according to the state of the art taking into account the principles of development lifecycle, risk management, validation and verification.	4.1	3.7	4.5	4.96	4.9
Devices where the safety of the patients depends on an internal power supply must be equipped with a means of determining the state of the power supply.	4.05	3.7	4.35	4.9	4.87
Devices where the safety of the patients depends on an external power supply must include an alarm system to signal any power failure.	4.78	4.56	4.3	4.74	4.3
Devices intended to monitor one or more clinical parameters of a patient must be equipped with appropriate alarm systems to alert the user of situations which could lead to death or severe deterioration of the patient's state of health.	3.82	3.48	3.88	4.36	3.66
Devices must be designed and manufactured in such a way as to minimize the risks of creating electromagnetic fields which could impair the operation of other devices or equipment in the usual environment.	3.88	3.89	4.9	3.8	3.8
Devices must be designed and manufactured in such a way as to avoid, as far as possible, the risk of accidental electric shocks during normal use and in single fault condition, provided the devices are installed correctly.	4.52	1.72	4.87	3.1	4.67
Devices must be designed and manufactured in such a way as to protect the patient and user against mechanical risks connected with, for example, resistance, stability and moving parts.	4.85	4.35	2.61	2.6	1.4
Devices must be designed and manufactured in such a way as to reduce to the lowest possible level the risks arising from vibration generated by the devices, taking account of technical progress and of the means available for limiting vibrations, particularly at source, unless the vibrations are part of the specified performance.	2.1	4.3	4.1	3.8	1.5

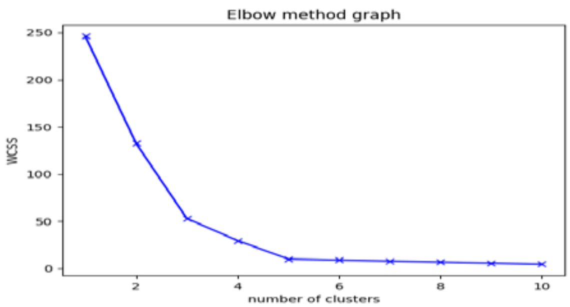

Fig. 2. Elbow Method Graph for Prioritization and Suitability Attributes.

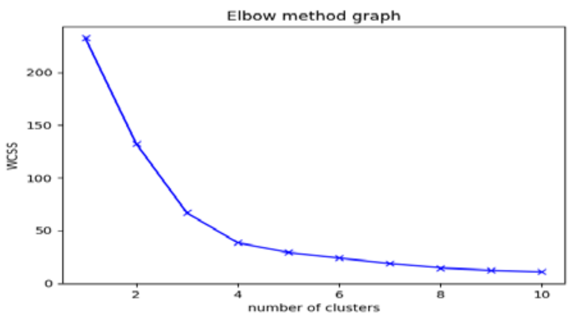

Fig. 3. Elbow Method Graph Prioritization and Achievability Attributes.

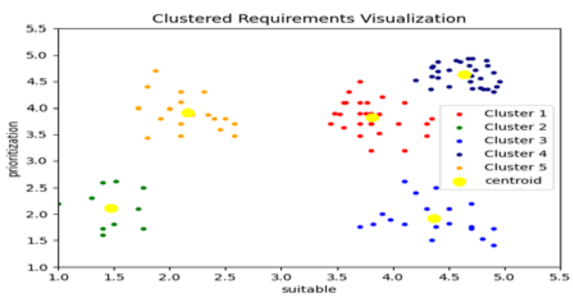

Fig. 4. 2D Visualization for Five Clustered Requirements.

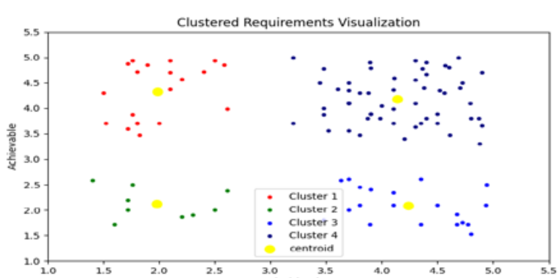

Fig. 5. 2D Visualization for Four Clustered Requirements.

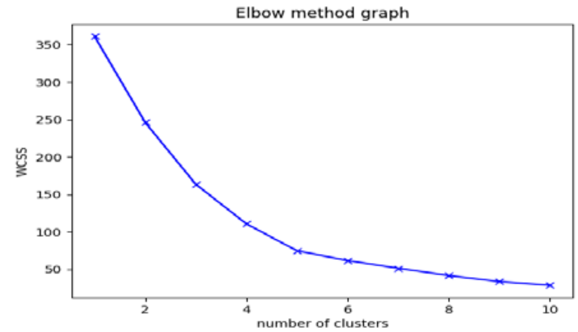

Fig. 6. Elbow Method Graph for Assigned Three Attributes Prioritization, Achievability and Suitability.

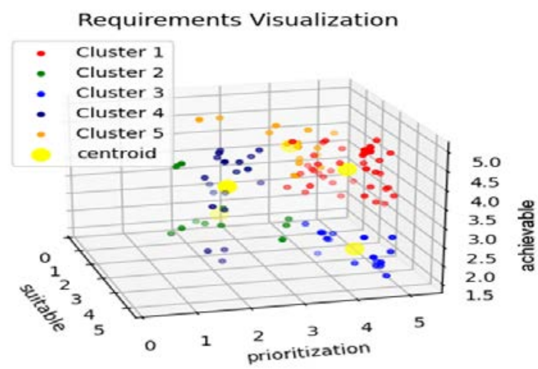

Fig. 7. 3D Visualization for Clustered Requirements.

In Fig. 7, K-means++ algorithm runs based on the evaluation of three attributes, which are suitability, prioritization, and achievability, Requirements are clustered into five clusters as the Elbow method showed. The Requirements sorted and visualized through 3-Dimensions matplotlib.

Silhouette method is applied to evaluate the clustering. This technique used to determine the performance and how much the clustering technique that has been used is correct. [26] Silhouette scope determines the measures between every object in the cluster and the other objects from other clusters. [26] Silhouette coefficient range from -1 to 1, where 1 implies that clusters are well separated and the objects are related to each other at the same cluster, while 0 implies that clusters are not separated well and distance between clusters are too close. -1 implies that objects and clusters are wrongly appointed. [27] Silhouette score coefficient is calculated for requirements to determine the optimal number of clusters. It tested from 2 clusters to 6 clusters and the result is presented here in Fig. 8 to 12.

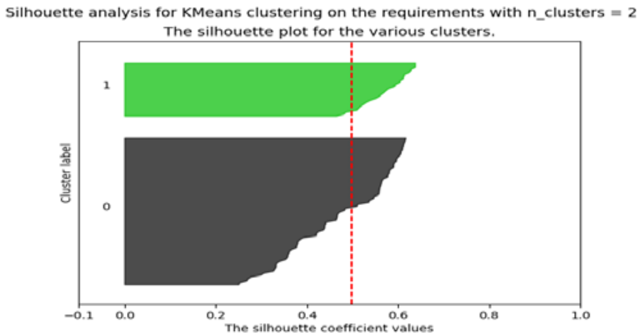

Fig. 8. The Silhouette Coefficient Value for Two Clusters.

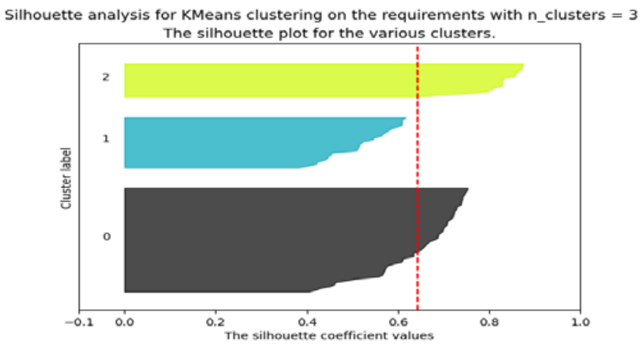

Fig. 9. The Silhouette Coefficient Value for Three Clusters.

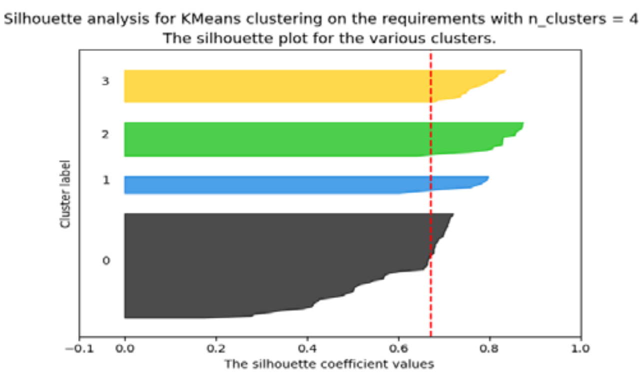

Fig. 10. The Silhouette Coefficient Value for Four Clusters.

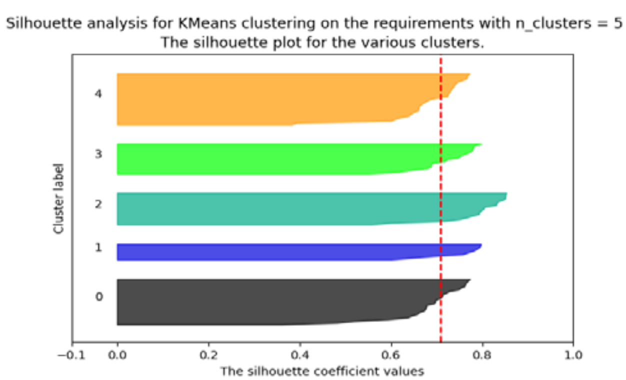

Fig. 11. The Silhouette Coefficient Value for Five Clusters.

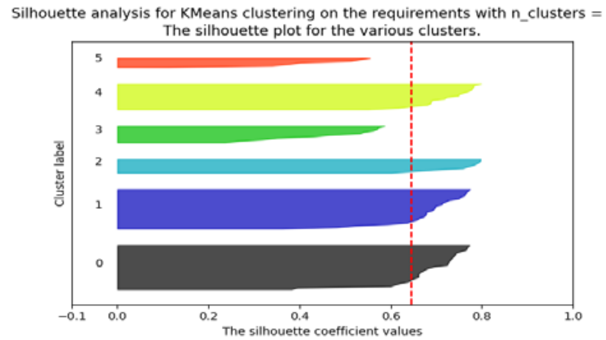

Fig. 12. The Silhouette Coefficient Value for Six Clusters.

Fig. 8 to 12 shows the silhouette analysis for Kmeans clustering. The cross column on the x axis shows the silhouette score as it's explained in Table III. The thickness of the silhouette plot represents the related requirements for each cluster. Fig. 11 shows the silhouette score is 0.71.

In Table III, shows silhouette score for the different number of clusters.

Fig. 4 showed that there are five clusters. Labeling of these clusters showed in Table IV.

Since the requirements were labeled then the data can be classified. Data were split into a training and testing set; with 80% for training and 20% for testing. The data splitting is to confirm the predicting of the class of any new element. The number of tested requirements is 21. The Confusion matrix is a visual evaluation technique used in machine learning. It presents the actual class result associated with the prediction class result [28]. The result of the confusion matrix is presented in Table V and the accuracy score was 1 for the tested cases.

TABLE III. AVERAGE SILHOUETTE SCORE FOR NUMBER OF CLUSTERS

Number of clusters	Silhouette score
2	0.49
3	0.64
4	0.67
5	0.71
6	0.64

TABLE IV. LABELING THE CLUSTERS

Cluster Number	Label Name
1	High Priority High Suitability
2	Very Low Priority Very Low Suitability
3	High Suitability Very Low Priority
4	Very High Priority Very High Suitability
5	High Priority Low Suitability

TABLE V. CONFUSION MATRIX FOR THE TESTING SET

Class 1	Class 2	Class 3	Class 4	Class 5
8	0	0	0	0
0	3	0	0	0
0	0	6	0	0
0	0	0	2	0
0	0	0	0	2

In Table V, 21 requirements had been tested with the classification technique Naïve Bayas. Results are shown in the table that eight requirements belong to class 1. Three requirements belong to class 2. Six requirements belong to class 3. Two requirements belong to class 4. Two requirements belong to class 5.

The classification report is used to assess the accuracy of a classification algorithm's predictions. The classification report presents the precision, recall, f1-score.

Precision = (TP/(TP+FP))

Recall = (TP/(TP+FN)).

The classification report shows that the precision is one for the five classes. The recall is one for the five classes. The F1-Score is one for the five classes.

VI. CONCLUSION AND FUTURE WORK

In this research; a novel approach "Conceptual mapping for health care non-functional requirements; CMHR" is applied to enhance requirement engineering analysis of healthcare systems. The approach focuses on ranking requirements using a set of attributes and calculates the mean value of each requirement for every attribute. CMHR is applied using the K-means++ algorithm to gather the related requirements into one group according to its semantic similarity. Semantic similarity is captured using conceptual mapping of the requirements. The CMHR approach can be extended to any different number of clusters. Clusters can be defined based on two or three attributes to sort the data based on the attributes and visualize it. Assigning labels to the clusters is essential to identify every cluster and requirement, in order to make a classification. CMHR offers an automatic classification for a new requirement. CMHR is applied to medical device requirements and generated five clusters of the requirements depending on prioritization and suitability with a silhouette score 0.71. Also, generated four clusters depending on prioritization and achievability. It generated five clusters based on three attributes. CMHR can work dynamically between any two or three attributes. In future work, CMHR will be applied on more than project to consume the time will be saved to finish the project. More attributes will be found to enhance CMHR approach and to find relations between requirements. Swarm intelligence can be applied to get more enhancement for the proposed approach.

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Improved Rough-fuzzy C-means Clustering and Optimum Fuzzy Interference System for MRI Brain Image Segmentation

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***Abstract*—The categorization of brain tissues plays a vital role in various neuro-anatomical identification and implementations. In manual detection, misidentification of location and sound of unwanted tissues may occur due to visual fatigue by humans. Also, it consumes more time and may exhibit enormous partially inner or outer the manipulator. At present, automatic identification of brain tissues in MRI is vital for investigation and healing applications. This work proposed MRI image tissue segmentation using Improved Rough Fuzzy C Means (IRFCM) algorithm and classification using multiple fuzzy systems. Proposed research work comprises four modules: pre-processing, segmentation, categorization, and extracting features. Initially, the elimination of boisterous occur in the given image is done through pre-processing. After the pre-processing, segmentation is carried out for the pre-processed brain image to segment the tissue based on clustering concept using Improved Rough Fuzzy C Means algorithm. Later, the features of Gray-Level Co-Occurrence Matrix (GLCM) are extracted from segmentation, and the features extracted from segmented images are applied to Optimum Fuzzy Interference System (OFIS). Then the entire system parameters are optimized using Enhanced Grasshopper Optimization Algorithm (EGOA). Finally, the novel OFIS classifier helps to classify the brain-based tissue images as Gray Matter (GM), White Matter (WM), Cerebrospinal Fluid (CSF), and Tumor Tissues (TT). The results using MRI data sets are analyzed and compared with other existing techniques through performance metrics to show the superiority of the proposed methodology.**

Keywords*—Cerebrospinal fluid; fuzzy interference system; enhanced grasshopper optimization algorithm; improved rough fuzzy c-means clustering

I. Introduction

In abnormal and normal brain tissues studies, Automatic classification of brain tissue from MRI is very important [1]. The troop of unidentified cells that are grown in the brain or around the brain is said to be a brain tumor, and it is the maximum cause of increasing impermanence among adults as well as children across the world. Few brain tumors are benign (non-cancerous), and some are malignant (cancerous) [2]. The main aim of identifying images in the brain-based tumor is to separate the sufferer-specific clinical information and their distinctive characteristics. The collected information was inserted in multidimensional image data; after detection and locality of disease, it instructs and monitors the interventions, and it undergoes disease treatment, clinical observation, and analyzes the stage of disease [3]. In any part of the body, if there are uncontrolled tissues grown is said to be a tumor. It is classified into two stages: primary and secondary. If it is starting stage, then it is said to be primary and if the tumor spreads around and grown in their own way is known to be secondary. Moreover, CSF (Cerebrospinal Fluid) is mainly affected by the tumor [4-5]. The automatic identification and separation of brain tumors is a difficult task and faces many issues in identification. In an automatic computerized system, the separation is a challenging task in brain tumors, and it involves the nature of the disease, intensity, and identification of the shape of MRI images.

The most used object in image segmentation which was shown that mutually exclusive regions which consist of pixels and other regions included homogenous, has implemented with predefined criteria [6]. Brain tumor segmentation has involved different methods of separating different tumor tissue, which consists of GM, WM, and CSF [7]. Its goal in segmentation has shown that changing the depiction in the image is more meaningful and easier to find out. It was used to order the local object and its boundary images. Finally, the result says that the seat of regions mostly covers the entire image [8]. There are many challenging issues in the image segment, which has been developed by a modified approach, and it is mostly implemented in all types of applications and figures. Moreover, the choice has the proper method to find out the image in difficult problems [9]. The major issue in the brain tumor segment indicates that the tumor varies its shape, size, and location-based on image intensities [10]. The manual segment of a brain tumor was derived by the human experts, and it has to be long time, which makes clearer that a computer-aided system for a brain tumor has observed an advisable method.

Clustering is mostly used in MRI image segments. The clustering process is defined by a grouping of pattern arrangements. Cluster analysis says various unsupervised learning techniques that are applied to resolve the changes in cluster problems. There are many various unsupervised instruction techniques such as s k was indicated by Fuzzy C means algorithm etc. and it indicates the K as simplest [11]. To group the objects, K-means clustering is implemented, and it confides on the ascribe characteristic into k no of groups. In k-means clustering, trooping is implemented on Euclidean distance among the cluster center and information [12]. In real-time problem solving such as target identification, image separation, mineralogy, uranology, and images in medical Fuzzy C-Means clustering is used, and it acts as a clear training method. The clustering methods are very important since the images in medical are limited pixel quantity, poor distinction, boisterous, and the variation is non-uniform [13-14]. In the brain image of MRI, the edges of several tissues are unclear. So, clustering methods are commonly applied for the identification and detection of brain tumors.

Research work helps to identify the tissue type of MRI brain images. For the purpose of tissue classification, at first, speckle noise removal is applied in the pre-processing stage. Next to pre-processing, segmentation-based clustering is carried out by means of the Improved RFCM method based on pixel similarity. Then GLCM has extracted the particular characteristics of the improved method. After the feature extraction stage, the OFIS classifier is performed to classify the brain tissue images where its parameters are optimally selected using Enhanced GOA. The remaining sections of the proposed work are discussed below, and the related work of several researchers is described in Section 2. Problem definition and contribution of the research work are given in Section 3, and Section 4 highlights the overall background of the study. Section 5 elaborates the proposed methodology. In Section 6, the result is summarized, and the conclusion of the presented work is provided in Section 7.

II. Literature Survey

In current days, recognition of tumors and their classification system is the most developing research area. Hence, Hao Dong et al. [15] has developed an automatic detection of brain tumor and segmentation approach. Here, this developed approach is utilizing the deep convolution framework based on the U-Net methodology. Moreover, the proposed method segmentation process is compared with various physically defined ground accuracies. The comparison demonstrates segmentation process is robust and effective. In addition, to validate the effectiveness, the entire tumor areas, and higher tumor areas outcomes are compared with core tumor areas. Here, the developed method provides the brain tumor segmentation of particularly affected persons without physical intrusion. Also, this approach is significant permits the objective injury analysis for medical responsibilities like that patient observing diagnosis, arrangement of treatment, and diagnosis. Besides, this method is evaluation is mainly based on the multimodal image segmentation dataset. These datasets include higher and lower grades of brain tumor cases as 220 and 54, respectively. To verify the efficiency of the segmentation procedure, cross-validation is taken.

Recognition of tumors in the brain is the most significant performance in these modern days. Hence, the automatic detection system is developed by Soltaninejad et al. [16]. Moreover, this detection scheme detects the brain tumor in the abnormal tissue related to the segmentation process. This approach mainly bases on the Fluid- Attenuated Inversion Recovery (FLAIR) with MRI image segmentation. Here, the experimental outcomes are having high segmentation performance and higher recognition ratio. Moreover, the performances are validated based on the ERT classifier system. Consequently, the detection sensitivity, error rate, and overlap measure of the proposed technique have attained 6%, 89.48%, and 0.88% separately. In addition, multimodal tumor segmentation performance outcomes are summarized below, 88.09% detection sensitivity, 6% of error rate, and 0.88% dice overlap amount. Here, the developed detection sachems take the original brain tumor images. To classify the images superpixel approach is utilized. Moreover, the original brain tumor image features consist of four types of classification. That is, curvatures, intensity bases feature classification, Gabor textons, and fractal examination.

Cabria et al. [17] has developed a Potential Field Segmentation (PFS) algorithm based original MRI brain tumor segmentation process. Also, the author presents and investigates the outcomes of the created PFS and other approaches to attain the bonded segmentation. Here, the proposed PFS method is mainly based on the Potential Field Clustering (PFC) and other recently proposed clustering approaches concept is incorporated with PFS. Moreover, the term “mass” is represented as a potential field to create the intensity of the MRI pixel vision. Particularly, each and every pixel of MRI is estimated, and a smaller area of the brain tumor pixel was related to the adaptive potential threshold. Moreover, the segmentation condition is “small potential”. It is automatically verifying the brain tumor pixels for a long time. Therefore, there is no “mass” and larger potential surroundings are much larger than the segmentation criteria. Then, the attained performances results are compared with different approaches consist of MRI bases benchmark dataset with multimodal tumor segmentation.

Mohammad et al. [18] have proposed a Deep Neural Networks (DNNs) bases automatic brain detection method is utilized. In this method, take the MR images to perform the low and high-grade networks. Consequently, the brain tumor is affecting is appeared in anywhere of the brain region. Also, the brain tumor is classified based on the size, shape, and divergence; these are the issues in the machine learning methodologies. In addition, the low flexibility and lower ability are the surveyed problems of ML techniques. To overcome these types of issues Convolution Neural framework (CNF) is developed through the Deep Neural Networks. Moreover, the newly proposed CNF structure is totally different from the conventional methods. The process of CNF is initially done with the local features and global contextual features. Implementations are done in the 40 fold speed up with a fully connected layer of the CNF. Finally, the outcomes of the CNF have validated bases on the comparison of the additional source of the dataset for succeeding CNF.

Rajinikanth et al. [19] have developed an innovative algorithm depend on the meta-heuristic optimization method. To evaluate the MRI brain tumor classification, the proposed method is utilized. Moreover, the proposed method improves the mines tumor core, as well as edema sector of the Teaching Learning Based Optimization (TLBO), based brain MRI integrating. Additionally, entropy examination and level set examination-based segmentation procedures are taken to execute the entire process efficiently. Here, the proposed approaches are implemented in flair, T1C, and T2 modalities. Also, the experimental performances are estimated using CEREBRIX and BRAINIX datasets. Furthermore, the optimization algorithm is validated based on the MICCAI separation of brain tumors by multimodal image separation challenge at the 2012 dataset. Attained outcomes are compared with Jaccard index values in terms of accuracy, precision, specificity, and sensitivity. Therefore, the developed segmentation process is medically important.

The accurate identification of tumors in the brain is a difficult and challenging task. To address this issue, Soltaninejad et al. [20] presented a 3D supermodel-based training method for the identification of tumors in multimodal MRI. Collected information and characteristics from multimodal MRI includes systemic MRI, and it results in accurate identification of brain images. Super voxels were created for applying the information, and a variety of characteristics is calculated by Gabor filters for every super voxel. The calculated characteristics are applied to the RF (random forest) classifier to categorize the tumor. The result shows that it gives better results in the separation of tumors. For increasing accuracy, the multimodal MRI is added, and it shows improvement in accuracy, and it provides better delineation among all tumor grades. The detection of brain tumor using multimodal MRI, it is the fastest method; it gives high accuracy and classifies the brain tissue as healthy or brain edema.

Nabizadeh et al. [21] had presented an automated identification of brain tumors in MRI for evaluation of the changeability and difficulty of the position, size, form, and appearance. Some techniques were used in multi-spectral anatomical MRI because of the similarities in intensity between the tissues normally found and injured brains. However, in multi-spectral MRI, there are some limitations in cost and time, and it faces some difficulties; to conquer this, a single-spectral anatomical MRI was developed to detect the tumor tissues. Also, he presented a fully automatic system it detects the tumor area and describes the portion which is damaged. As a result, the experiment shows that it successfully segments the tissues with less difficulty in computation and high accuracy. The benefit of a single contrast mechanism is separating the tissue segments, and it can able to identify the tumor tissues. Furthermore, it also includes an overview that evaluates the benefits of statistical characteristics over Gabor wavelet characterization by applying various classifiers.

III. Problem Definition

Brain tissue categorization in MRI is a vital stage in identifying the disease, diagnosis, planning for surgery, and process of treatment. In present days, MRI classification is a challenging task despite several existing artifacts such as boisterous, complexity in images, and incomplete volume effect. In automatic brain classification, some of the methods are complex, and few are not sufficiently accurate for a certain application. The proposed works contributions are described below:

- The main principle of proposed work is to analyze which type of tissue is occurred in the brain is analyzed from MRI images collected from the database.
- For segmentation, clustering is carried out to segment the brain tissue using Improved RFCM. Here the improved technique manages overlapping clusters.
- Five GLCM features, namely interaction, distinction, energy, disarray, and quantity variance alone, are extracted for the optimum solution.
- To obtain the optimal solution, EGOA is utilized in FIS, which helps to classify brain tissue MRI by optimizing the system structure.

IV. Background of the Study

Several processing methods were proposed by the existing researchers for the separation and categorization of tissues in the brain for MRI. In early researches, numerous techniques were developed and discussed for identifying the brain tissues in MRI; fully automated detection, extraction of features, segmentation, and categorization is essential. A series of steps involved in image processing is utilized on MRI images to do brain tissue segmentation, and categorization of images that were inspired from proposed algorithms, and its background knowledge is analyzed in this section.

A. Fuzzy C-Means Clustering Algorithm

Generally, C-Means are the commonly used and most known clustering models because it is a smallest square model. Fuzzy C-Means is very widespread due to its handling capability of overlying clusters when compared with C-Means clustering algorithm. Based on fuzzy integration, FCM instructs each pixel (data points) to clusters. Let $Y = \{y_1, y_2, \dots, y_l, \dots, y_O\}$ be the set of O objects and $W = \{w_j, \dots, w_j, \dots, w_d\}$ be the set of d centroids; where $Y = \{y_1, y_2, \dots, y_l, \dots, y_O\}$ be the set of d centroids; where $y_l \in S^n$, $w_j \in S^n$and $w_j \in Y$. It separates Yinto $d$clusters by iteratively reducing the function of objectives:

$$K = \sum_{i=1}^{d} \sum_{y_l \in C(Y)} \left(\eta_{jl}\right)^x \|y_l - w_i\|^2 \quad (1)$$

Where $1 \leq n < \infty$ is the operator in fuzzifier, w_i represents the j^{th} centre of force correlated to cluster Y_j, $\eta_{jl} \in [0,1]$ is the patterns fuzzy integration y_l to cluster Y_j, and distance criteria is represented as $\|\bullet\|$. The resulting partition is controlled by fuzziness parameter n, where $n = 2$ is used. The pixel near to a centre of cluster achieve membership value as high then the function of objective is reduced and those distant from it are designate the membership value as low. The value of membership depends on the proportional distance of the object to centre of cluster as inverse. Algorithm is outlined as follows:

- Allot initial centre of force w_j, $j \in 1$ to $d$for clusters.
- Find d value of membership for O pixel by following:

$$\eta_{jl} = \frac{1}{\sum_{i=1}^{d} \left(\frac{\|y_l - w_j\|}{\|y_l - w_i\|}\right)^{\frac{2}{n-1}}} \quad (2)$$

And update cluster centers as,

$$w_j = \frac{\sum_{l=1}^{O} \eta_{jl} \times y_l}{\sum_{l=1}^{O} \eta_{jl}} \quad (3)$$

Subjected to

$$\sum_{j=1}^{d} \eta_{jl} = 1 \nabla land 0 < \sum_{l=1}^{O} \eta_{jl} < 1 \quad (4)$$

In a cluster, each dataset is assigned, and it carries the membership value is high. If the membership value is low, then the belongingness is also low. Iterate steps two again until the center of gravity stabilizes that are the previous iteration is identical to the present iteration, and there is no additional work. The point which is to be noted is the dependency of FCM on proportional interval among the centre of clusters and the data points, which makes it delicate to boisterous.

B. Rough Set Theory

Rough set theory is based on idea of space of approximation and it is designated by two attributes. Lower estimation, $S_U(Y)$, Upper estimation of the Rough set, $S_L(Y)$ is describe as, Here, subset is denoted as $Y \subseteq Uni$,and Uni is represented as universe, S is the Uni connection of equivalent then we have:

$$S_U(Y) = Uni\{Z \in Uni/S | Z \subseteq Y\} \quad (5)$$

$$S_L(Y) = Uni\{Z \in Uni/S | Z \cup Y\} \neq \varphi \quad (6)$$

Where φ represents empty set.

The lower approximation $S_L(Y)$ is the union of all the elementary sets which are subsets of $Y$and the upper approximation $S_U(Y)$ is the union of all the elementary sets which have a non-empty intersection with Y. The interval $B(Y) = [S_L(Y), S_U(Y)]$ is the delineation of a normal set Yin the space of approximation $< Uni, S >$ or simply it is called Y rough set. The bottom set of approximation describes that all elements were surely refer to Y, whereas in approximation is upper, and then it is a collection of those elements that definitely belong to Y. An object y_l can be lower most part of any approximation. If $y_l \in S_L(Y)$ of cluster Y then simultaneously $y_l \in S(Y)$. If y_l is not a part of any lower approximation, then it belongs to two or more upper approximations.

C. Grasshopper Optimization Algorithm

Optimization refers to attain the best result in a solution space in regard to some predetermined norms. Among several optimization algorithms, GOA is considered to be the efficient technique to find out the best solution. Generally, Grasshopper is a catastrophic insect in agriculture, and it has two stages, nymph and adulthood. Normally, the nymph Grasshopper has no wings, and it eats all vegetation in its path. After a period of time, the wings were grown slowly, and it flies in the air and moves to a large distance in a certain time. Moreover, the grasshoppers' nature is individual; and grasshoppers were joining as a big hive of all beings. The measurements of the hive may be of small size, and it is incubus for farmers. The behavior of hive is found in both phases of grasshoppers, and it is a unique aspect of grasshoppers. The key distinctive of the hive is a slow movement in their phase of larval, and it is the fewer steps for grasshoppers. Distant range and sudden motion is the necessary characteristic of the troop in adulthood. The other characteristic of grasshopper troops is searching of foods by dividing their process of search into two, namely exploration and exploitation. Here each Grasshopper illustrates an answer in the community. Fig. 1 shows the general framework of the grasshopper optimization algorithm:

To replicate the swarming behavior of grasshopper, mathematical model is done and is represented as follows:

$$Y_j = R_j + H_j + A_j \quad (7)$$

Where,Y_j represents the $j - th$ grasshopper position, R_j is the interaction on social, H_j is the $j - th$ grasshopper gravity force, and A_j shows the advection of wind.

1) Social interaction: The element fully replicates the movement of grasshoppers, yet the component which is mainly originated from the grasshoppers and it is discussed below:

$$R_j = \sum_{\substack{i=1 \\ i \neq j}}^{M} t(e_{ji})\, \hat{e}_{ji} \quad (8)$$

Where, distance between $j - th$ grasshopper and $e_{ji}$is $i - th$ grasshopper and it is defined as,

$$e_{ji} = |y_i - y_j| \quad (9)$$

Here, t is a function to define the social forces strength, as shown in equation (9) and e_{ji} is a unit vector from the $j - th$ grasshopper to the $i - th$ grasshopper which can be defined as,

$$\hat{e}_{ji} = \frac{y_i - y_j}{e_{ji}} \quad (10)$$

The function, t defines the social force, is calculated as follows:

$$t(s) = g f^{\frac{-v}{m}} - f^{-s} \quad (11)$$

where g indicates the intensity of attraction and l is the attractive length scale. The grasshopper's impact on social interface is shown as function t. The parameters were adjusted for social force g and m which is not suitable for applying strong forces among grasshoppers with large distances among them.

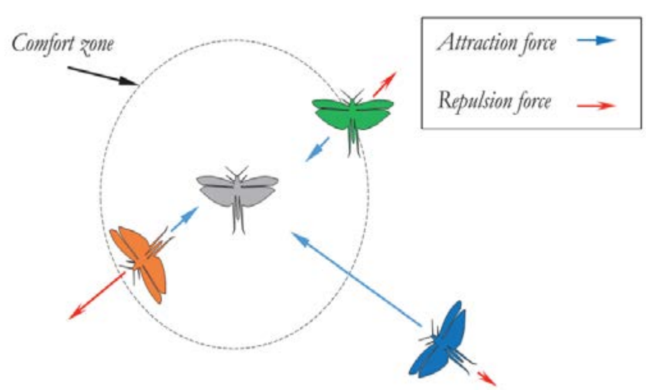


Fig. 1. Generalized Framework of Grasshopper Optimization Algorithm.

For providing random behavior, the equation can be describe as

$$Y_j = s_1 R_j + s_2 H_j + s_3 A_j \tag{12}$$

Where s_1, s_2 and s_3 are random numbers in [0, 1].

2) Gravitational force: The enhanced grasshopper force of gravity is represented below:

$$H_j = -h\hat{f}_h \tag{13}$$

Where h is the constant value in gravitational and $\hat{f}_h$ shows a union vector towards the center of gravity.

3) Wind advection: The grasshopper advection can be calculated as follows:

$$A_j = v\hat{f}_w \tag{14}$$

where, v is constant drift and $\hat{f}_w$ is a unity vector in the direction of wind. Movements of grasshoppers are coordinate with the direction of wind because it has no wings. The values of $T, H\&B$ are substituted in equation (7) and is expanded as follows:

$$Y_j = \sum_{\substack{i=1 \\ i\neq j}}^{M} t\left(\left|y_i - y_j\right|\right)\frac{y_i - y_j}{e_{ji}} - h\hat{f}_h + v\hat{f}_w \tag{15}$$

where, M represent the number of grasshopper.

V. Proposed Brain Tumor Tissue Detection Methodologies

The primary objective is to outline and build up a technique for classifying MRI brain images using various stages. The redundant data will be reduced by the rough sets and also reduced data to achieve information dimension and also reduction in accuracy and sensitivity. And also, problems in the definition of fuzzy similarity relations. These limitations need to overcome. Therefore, to achieve a better outcome, the Improved Rough FCM is used. The block illustration of the proposed methodology is demonstrated in Fig. 2. Subsequently, a novel brain tissue classification method using MRI images is presented by utilizing Improved Rough Fuzzy C Means algorithm and optimal fuzzy interference system (OFIS) to classify the brain tumor as background (BG), gray matter (GM), White matter (WM), Cerebrospinal Fluid (CSF), and tumor tissues (TT). To accomplish this, the proposed framework is comprised of five modules, namely,

- Pre-processing by speckle noise removal
- Segmentation using Improved RFCM.
- GLCM based feature extraction.
- Brain tissue Classification by OFIS.
- Optimization by means of EGOA.

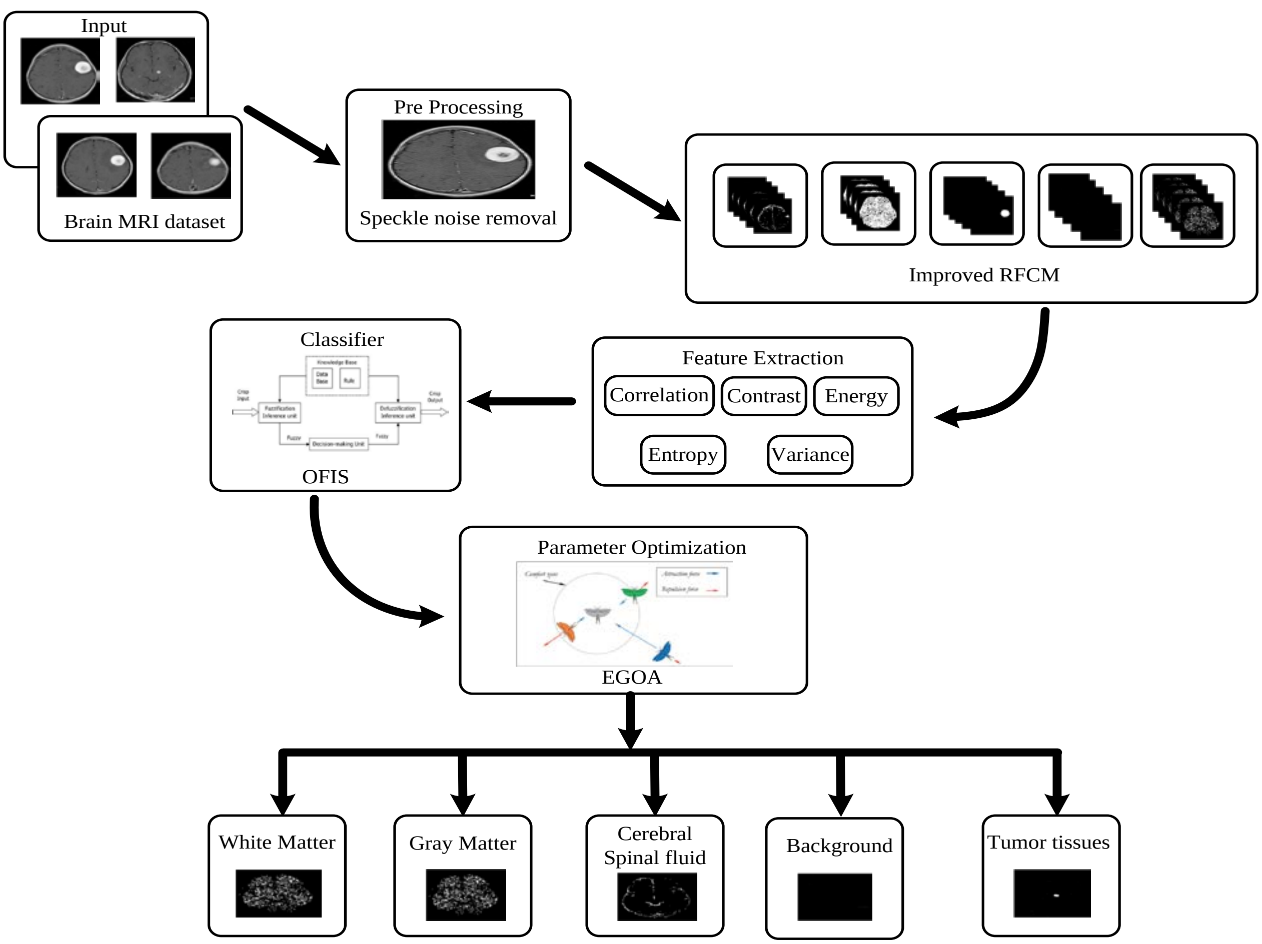


Fig. 2. Block Diagram of the Proposed Methodology.

Initially, the brain MRIs are given to the pre-processing stage, where speckle noise removal is applied to remove the noisy content of the input image. Further segmentation is carried out to segment the tissue based on clustering using Improved RFCM. Then the features are extracted using GLCM. The OFIS classifier is generated for those extracted features, and its parameter gets optimized through EGOA, where the brain tissues are classified as WM, GM, CSF, BW, and TT. The proposed methodology is briefly clarified in the below sections.

A. Pre-Processing

Pre-processing is carried out to eliminate contaminants or noisy data from the picture. Moreover, one of the primary challenges in the processing of medical images is to reduce noise. Different techniques for noise reduction were addressed in prior works. Speckle noise is usually observed in medical pictures. This noise can affect the segmentation quality of the image. The mathematical model of the speckle noise can be represented as:

$$h(o,n) = \xi(o,m) + g(o,n) * v(o,n) \quad (16)$$

Where, $h(o,n)$ defines the input image observed from MRI, $v(o,n)$ represents the multiplicative and the speckle noise additive element is denoted as $\xi(o,n)$, the sample image both axis is represented as $v(o,n)$. The additive noise element is neglected for the noise elimination, which is expressed in equation (17).

$$h(o,n) = g(o,n) * v(o,n) \quad (17)$$

The above equation defines to be the noise eliminated image. After reducing the noise, the image is segmented based on pixel similarity using Improved RFCM algorithm.

B. Tissue Segmentation using Improved Rough Fuzzy C-Means Clustering Algorithm

After pre-processing, the brain MRI images are formed as a cluster concept for the function of tissue segmentation. Novel improved fuzzy C-Means method is used to segment the brain tissue types based on pixel similarity. Consequently, the hybrid rough fuzzy C-Means algorithm is compared with the other methods for validating the effectiveness of the developed model in segmenting brain MRI images.

1) Improved rough fuzzy c-means clustering: A Rough Fuzzy based clustering procedure is a combination of rough sets along with fuzzy sets methods. The rough sets approximation of upper and lower in addition to the concept of the membership of the Fuzzy set is integrated into the C-means clustering. The RFCM partitions a set of objects as o into clusters d by minimizing the objective function.

$$K(Uni,W) = \begin{cases} \psi_{low} \times \beta + \psi_{high} \times \alpha, if S_L(Y_j) \neq \varphi, C(Y_j) \neq \varphi \\ \alpha, if S_L(Y_j) \neq \varphi \\ \beta, if S_L(Y_j) \neq \varphi \end{cases} \quad (18)$$

where

$$\beta \Rightarrow \sum_{j=1}^{d} \sum_{y_l \in S_L(Y)} \left\| y_l - w_j \right\|^2 \quad (19)$$

$$\alpha \Rightarrow \sum_{j=1}^{d} \sum_{y_l \in C(Y)} \left\| y_l - w_j \right\|^2 \quad (20)$$

Where W_j denotes the j^{th}cluster Y_j centroid, the ψ_{low} and ψ_{high} parameter corresponds to the qualified position of lower bound and border area, that leads to $\psi_{low} + \psi_{high} = 1$. Consider that η_{jl} has the identical membership function by means of that placed in fuzzy C-Means. From the computation of β using equation (19) that weights of objects in below approximation are fuzzified in RFCM. To some extent, the centroids updating using equation (19) may lessen the significance of objects in lower approximation and cause the subsequent centroids to float away from right areas [22]. To avoid this problem, a new centroids equation is proposed. The centroids updating for IRFCM is given in equation (21).

$$K(Uni,W) = \begin{cases} \psi_{low} \times \beta + \psi_{high} \times \alpha, if S_L^C(Y_j) \neq \varphi, C_1(Y_j) \neq \varphi \\ \alpha, if S_L^C(Y_j) \neq \varphi, C_1(Y_j) = \varphi \\ \beta, if S_L^C(Y_j) = \varphi, C_1(Y_j) \neq \varphi \end{cases} \quad (21)$$

$$\beta = \frac{1}{|S_L^C(Y_j)|} \sum_{x_j \in S_L^C(Y_j)} x_j \quad (22)$$

$$\alpha = \frac{1}{n_j} \sum_{x_j \in C_1(Y_j)} (\mu_{ij})^m x_j \quad (23)$$

$$n_j = \sum_{x_j \in C_1(Y_j)} (\mu_{ij})^m \quad (24)$$

Using this function, we can improve the clustering accuracy.

C. GLCM based Feature Extraction

After clustering, the feature extraction process is done to the segmented image. The functional extraction phase aims to reduce the original data set by identifying the essential characteristics. By selecting ideal characteristics, classification outcomes are strongly affected. The GLCM based extraction approach is used in this proposed study. Moreover, Haralick's GLCM calculated texture features are a typical approach for representing picture texture as they are easy to implement and result in a collection of interpretable texture descriptors. GLCM is a pixel pitch and direction statistical approach which analyses the picture texture through the spatial connection of the pixels. Let consider, GLCM $(p_{prob}, q, \varphi, r, s)$ regulates the pixel with intensity 'r' ensues in compared with another pixel 's' at distance 'q' and direction 'φ'. Also, the GLCM feature extraction can control up to 14 features. At this period, several of the most significant texture characteristics were determined such as correlation, energy, contrast, and entropy.

1) Correlation (F1): Correlation is defined as the duration of the link between pixels and their nearby pixels. Also, the correlation is estimated by the equation (25) as,

$$Corr = \sum_{r=0}^{P-1} \sum_{s=0}^{P-1} \frac{[r*s]*log(M(r,s)) - [\mu_b * \mu_c]}{\sigma_b * \sigma_c} \quad (25)$$

Where, μ_b, $\mu_c$and σ_b^2, is the mean and σ_c^2 is the variance of r, s, are given as,

$$\mu_b = \sum_{r=0}^{P-1} r \sum_{s=0}^{P-1} M(r,s); \mu_c = \sum_{r=0}^{P-1} s \sum_{s=0}^{P-1} M(r,s) \quad (26)$$

$$\sigma_b^2 = \sum_{r=0}^{P-1} (I_b(r) - \mu_b(r))^2;$$

$$\sigma_c^2 = \sum_{s=0}^{P-1} (I_c(s) - \mu_c(s))^2 \quad (27)$$

2) Contrast (F2): Because of the local similarity of a picture, contrast is stated as the change in luminance. Furthermore, it is estimated using the following equation (28).

$$Cont = \sum_{p=0}^{P-1} p^2 \{\sum_{r=1}^{P} \sum_{s=1}^{P} M(r,s)\}, |r - s| = p \quad (28)$$

where, $M(r,s)$ is represented as Co-occurrence Matrix.

3) Energy(F3): The energy also influences the uniformity of the images. Energy is defined as the total of the GLCM Angular Second Moment entry squares. The second angular moment is large if the picture is extremely homogeneous otherwise if pixels are very similar. The energy is calculated by the equation (28) as follows:

$$Ene = \sum_{r=0}^{P-1} \sum_{s=0}^{P-1} M(r,s)^2 \quad (29)$$

4) Entropy(F4): Entropy is defined as showing the quantity of image data to enable compression by evaluating image data loss. Consequently, the entropy can be articulated as equation (30) as follows:

$$Ent = -\sum_{r=0}^{P-1} \sum_{s=0}^{P-1} M(r,s) * log_2(M(r,s)) \quad (30)$$

5) Sum of Squares (F5): Variance or Sum of squares is an arithmetical system, and it is used in regression study to found the dissemination of data location.

$$V = \sum_{r=0}^{P-1} \sum_{s=0}^{P-1} (r - \mu)^2 \quad M(r,s) \quad (31)$$

This feature places relatively high weights on components which differ from the typical standard value which is referred as $M(r,s)$.

D. Optimal Fuzzy Inference System(OFIS) for Classification

To achieve the optimal classification, the correlation, energy, contrast, sum of square variances and entropy of extracted features are provided to the FIS method. There are three main operations performed in the fuzzy inference scheme: initial Fuzzification, evaluation of rule, and the process of Defuzzification. Fuzzy inference is the technique to map with a fuzzy logic from a given input to an output. Then the mapping offers a framework for making judgments or discerning trends. In the fuzzy inference scheme function, different types of process are proceed such as Logical Operations, Membership Functions (MF) and the rule of If-Then. For performing fuzzification process, collected all the extracted features values of segmented images and estimated all feature minimum (m_n) and maximum (m_x) values. The performance of fuzzification operated by the subsequent equations (32) and (33):

$$m_n L^{(Corr)} = m_{in} + \left(\frac{m_x - m_n}{3}\right) \quad (32)$$

$$m_x L^{(Corr)} = m_n L^{(Corr)} + \left(\frac{m_x - m_n}{3}\right) \quad (33)$$

Where $m_x L^{(Corr)}$ and $m_n L^{(Corr)}$ are the maximum and minimum limit standards of the feature $Corr$. The similar derivation are utilized for the features such as$(Cont)$, (Ene), (Ent) and (V) are required to compute the minimum and maximum limit values. The schematic diagram of the fuzzy inference system (FIS) is shown in Fig. 3.

In the fuzzification stage, the input crisp values of five features namely correlation $(Corr)$, contrast $(Cont)$, energy (Ene), entropy (Ent) and variances (V) are given to the OFIS classifiers which are transformed into fuzzy variables. Also, the membership function (MF) is evaluated for all fuzzy variable in this system. For each feature, fuzzy variables are classified in the range [0, 1] and are classified as Low (L), Lowest (LL), medium (M), high (H) and Highest (HH). Moreover, the fuzzy variables of the output are WM, GM, CSF, BG and TT. Triangular MF and Trapezoidal MF are used in this model to get optimal outcomes. These triangular MF and Trapezoidal MF are used for a boundary as well as intermediate variables. Fig. 4 and 5 shows the MF of fuzzy variables for the input variables and MF of the output variable.

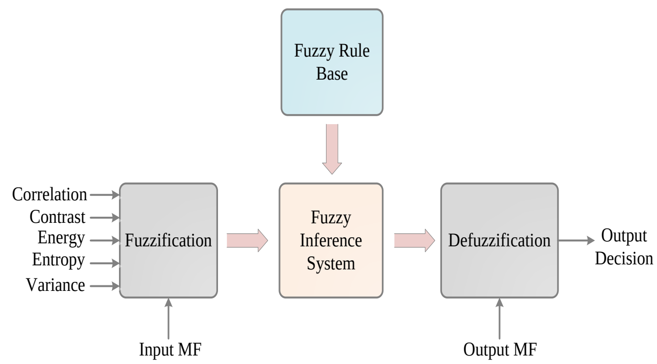


Fig. 3. Fuzzy Inference System Structure.

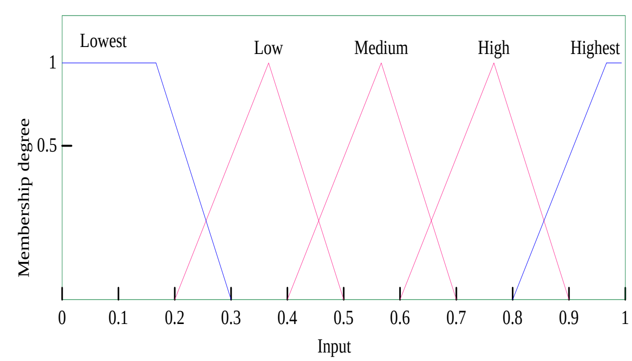


Fig. 4. Membership Function of Input Features.

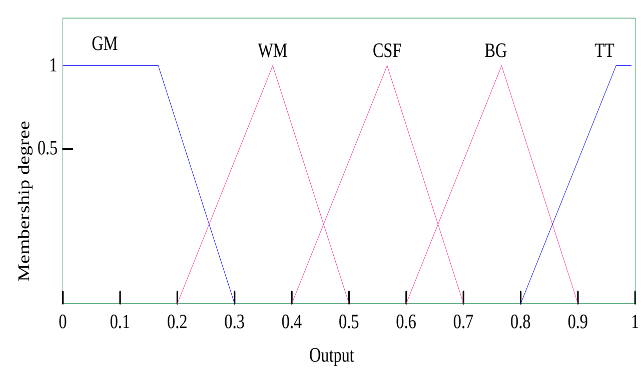


Fig. 5. Output Features of Membership Function.

In the Defuzzification (Z) stage, there are five processes provided to convert the fuzzy set of images into crisp rates for defuzzification. The techniques used for defuzzification are provided as follows as Last of Maxima Method (LOM), Bisector of Area Method (BOA), Mean of Maxima Method (MOM), Center of gravity (COG), and First of Maxima Method (FOM). Then, the sample function of fuzzy rules is demonstrated in Table I.

TABLE I. SAMPLE FUNCTION OF FUZZY RULE

Rule No.	F1	F2	F3	F4	F5	output
1	M	H	L	HH	LL	CSF
2	LL	M	H	L	HH	GM
3	L	H	L	HH	M	WM
4	H	LL	M	L	HH	WM
5	H	LL	M	LL	H	TT
6	HH	L	LL	HH	M	GM
7	M	H	H	M	L	TT
8	L	M	H	HH	HH	CSF
….	….	….	….	….	….	….
n	LL	H	HH	H	M	WM

As shown in Table I, F1, F2, F3, F4, and F5 represent the features for the given image. The rule basis of the FIS system should be updated for each time with the input and output parameters of the MFs altered. Therefore, optimum incorporation of these factors is highly important. The subsequent parameters of the FIS system must be optimized in this approach:

The input variable in triangular MFs must be optimized. For instance, if the triangular shape is assumed as three peak rates like p, q and s, which is illustrated in Fig. 6. The demonstration shows that the variables s and q are fixed when altered the value of p. In this developed FIS function, the triangular shapes are considered to all input variables and those parameters should be optimized for further processing.

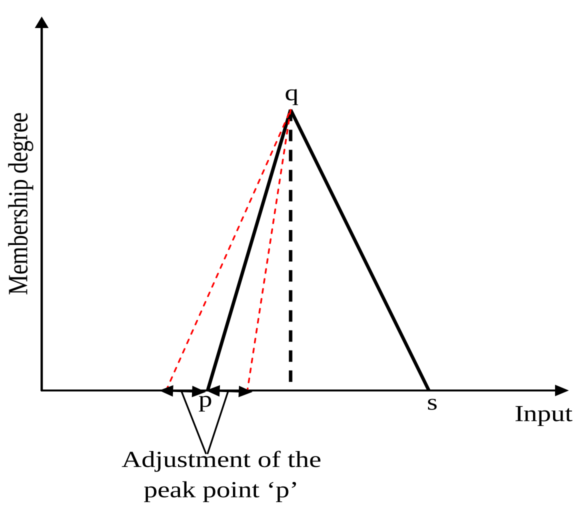


Fig. 6. Triangular MF Peak Points Position.

The optimal fuzzy rules are optimally chosen by the mid fuzzy rules. Consequently, optimal defuzzification process estimated along with the defuzzification methods (Z) and these parameters.

Thus, the FIS parameter has been chosen as the first solution. The selection of the best available solution provides maximum network accuracy. Therefore, an optimization technique is developed for FIS design difficulties that should be given, so that identify an ideal FIS and reduce preliminary modification time. A novel EGOA method is provided in this technique for the optimization of the FIS system parameters.

1) Parameter optimization by Enhanced Grasshopper Optimization Algorithm (EGOA): The parameter used in the FIS method is significantly optimized by the developed EGOA method for enhancing the performance of brain tissue, which is described in this section. The developed EGOA algorithm linked FIS system scheme step by step process is explained as follows:

a) Initialization: Initially, the parameters of FIS system is initialized arbitrarily and the EGOA parameters are also initialized. Furthermore, the population size N along with the candidate outcomes and agent's location is also initialized. The configuration of solution is represented in Fig. 7.

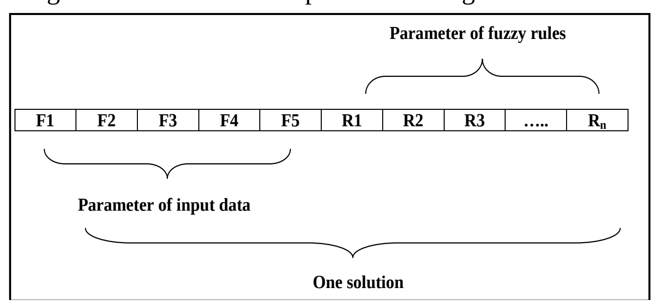


Fig. 7. Generalized Structure of the Solution.

Consider, d dimensional space for the initialized candidate solutions and agents location using equation (34).

$$Y = \{FIS_1, FIS_2, FIS_3 \ldots., FIS_d\} \tag{34}$$

Where, d^{th} dimension of optimal FIS solution or the agent location is denoted as FIS_d. Then, constraints of the input parameter are given as follows:

$$\{p_n \le x_n \le s_n; \quad n = 1,2,3,4 \tag{35}$$

b) Fitness calculation: After finishing the primary solution of generation process, the fitness value is evaluated. In this work, the utmost accuracy is considered as a fitness function. Also, the fitness rate of this proposed system is estimated by given equation (36).

$$Fitness = m_{ax}(Accuracy) \tag{36}$$

$$Accuracy = \frac{Total.TN + Total.TP}{Total.TN + Total.FN + Total.TP + Total.FP} \times 100 \tag{37}$$

c) Updation of using GOA parameters: Subsequently, the outcomes are updated using GOA parameters after the estimation of fitness value. The Updation function is given in equation (38).

$$Y_j = T_j + H_j + B_j \tag{38}$$

d) Crossover operator: To enhance the GOA, the cross over operator is added to GOA. The crossover operator is the function that is used to choose the genes from the chromosomes of parent and generate fresh offspring constraints. The operation in crossover is articulated by the various parameters such as permutation encoding, binary encoding, tree encoding and value encoding. The Fig. 8 shows cross over process.

e) Mutation operator: After the operation of cross over function, the better solution is updated via mutation. Also, the mutation operator is in compared to crossover that can seek for new regions. The Fig. 9 shows mutation operator. The exploitation fitness is considered as crossover operator and the exploration fitness function is worked by the mutation operator.

f) Termination criteria: Up to the ideal solution, the optimal FIS system, procedures are continued. Once the optimal FIS system has been achieved, the algorithm has closed the process of segmentation. This improved FIS system is utilized as a system for tissue categorization, which enhances the system's overall accuracy. The proposed EGOA method pseudo-code is demonstrated in Algorithm 1.

Algorithm 1: Pseudo code of proposed EGOA
Input : Parameter of FIS and parameter of GOA,
mutation rate 0.2, Crossover rate 0.1.
Output: optimized FIS.
Start:
Initialization: population size($\boldsymbol{M}$),$\boldsymbol{c_{max}}$, $\boldsymbol{c_{min}}$and maximum number of iteration ($\boldsymbol{s_{max}}()$)
Generate a random population ($\boldsymbol{Y}$)
Set the current iteration $\boldsymbol{s = 1}$
While ($\boldsymbol{s < s_{max}}()$) do
Evaluate the fitness of each solution by equation (37)
Renew the value of solution by equation (38)
Apply crossover operator
Apply mutation operator
$s = s + 1$
End while
End
Output: Optimized FIS

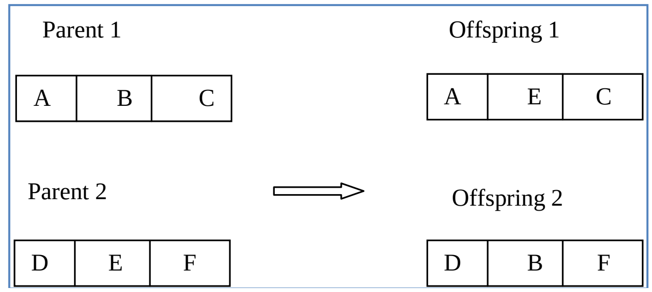


Fig. 8. Crossover Process.

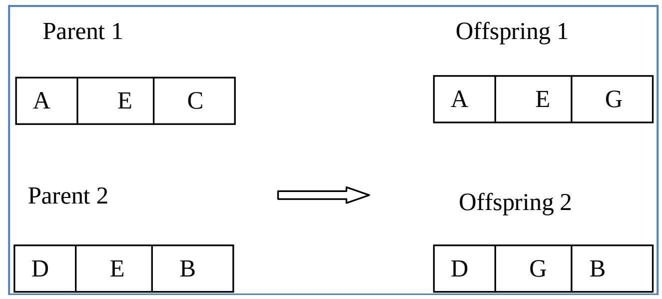


Fig. 9. Mutation Operator.

VI. Results and Discussion

In this section, the consequences and discussion around brain tissue segmentation and classification by using Improved RFCM and OFIS. The proposed configuration has been tested on the data sets of brain MRI named as BRATS 2017. Consequently, the performance of the proposed system is evaluated by the comparison of developed model outcomes with the conventional like Default FIS and KNN.

Accuracy is the proportion of true results among the total number of cases examined. Precision is a valid choice of evaluation metric when we want to be very sure of our prediction. True Positive, True Negative, False Positive, False Negative, sensitivity, and selectivity are the metrics used to know whether correctly predicted or incorrectly predicted the tumor. With these the decision can be taken that the tumor is detected properly or not.

A. Evaluation Metrics

The performance of the developed system is analyzed via the estimation of different evaluation metrics like, Specificity, Sensitivity, PPV, Accuracy, FNR, NPV, and FPR, which are detailed in the subsequent descriptions:

1) Sensitivity: The value of sensitivity is defined as the ratio of total true positives to the summation of total false negative and false positive value.

$$Sensitivity = \frac{Total.TP \rightleftarrows value}{Total.FN + Total.\rightleftarrows\rightleftarrows TP} \tag{39}$$

2) Specificity: The parameter of specificity is defined as the ratio of total true negatives to the summation of total true negative and false positive value.

$$Specificity = \frac{Total.TN}{Total.FP + Total.TN} \tag{40}$$

3) Accuracy: The accuracy metrics are estimated by the parameters value of specificity and sensitivity, which is expressed by equation(41).

$$Accuracy = \frac{Total.TN+Total.TP}{Total.TN+Total.FN+Total.TP+Total.FP} \quad (41)$$

4) Positive Predictive Value (PPV): The rate of PPV is estimated for the positive proportion of experimental and numerical results, which is articulated in equation(42).

$$PPV = \frac{Total.TP}{Total.TP+Total.FP} \quad (42)$$

5) Negative Predictive Value (NPV): The rate of NPV is estimated for the negative proportion of experimental and numerical results, which is articulated in equation(42).

$$NPV = \frac{Total.TN}{Total.TN+Total.FN} \quad (43)$$

6) False Positive Rate (FPR): The rate of FPR is estimated as the ratio of amount of overall incorrect positive forecast to the summation of overall true negative and false positive values. Also, it is estimated from the specificity as referred as 1-specificity value.

$$FPR = \frac{Total.FP}{Total.FP+Total.TN} \quad (44)$$

7) False Negative Rate (FNR): The rate of FNR is estimated as the ratio of amount of overall incorrect negative forecast to the summation of overall true positive and false negative values.

$$FNR = \frac{Total\ FN}{Total\ FN+Total\ TP} \quad (45)$$

B. *Experimental Setup*

The main innovation of this proposed methodology is tissue classification in MRI brain images by multiple phases. Moreover, the performance of the proposed multiple stage execution is validated with the use of various evaluation metrics estimation. In this article, the functions have been characterized the performance measure based on considered tissue types. The foremost aim of the proposed work is to recognize the type of brain tissue in input MRI's. Also, the comparative analysis is provided between the proposed OFIS technique with prevailing methodologies such Default FIS and KNN techniques. The sample collected image is specified in Fig. 10.

Initially, pre-processing is applied to the taken input images to remove the noisy content. Segmentation is carried out for the pre-processed images using the Improved RFCM algorithm. Consequently, the GLCM method is used for the extraction of foremost features from the pre-processed images. Finally, a novel OFIS classifier is executed to classify brain tissue images. The obtained segmented results for the given input images with proposed Improved RFCM technique is shown in Table II.

The proposed segmentation algorithm performance is validated in terms of segmentation, specificity as well as accuracy which are shown in Table III. In this article, IRFCM algorithm is utilized for the purpose of segmentation. IRFCM is a combination of roughest and fuzzy C-Means which is overcome the challenges present in the individual FCM method and rough set theory. While examining Table III, it shows that the proposed approach attains the utmost accuracy of 0.972. However, using rough FCM method has attained only 0.970 and 0.969 is achieved for the use of Rough K-Means algorithm. Similarly, sensitivity and specificity also proposed approach attain the better results.

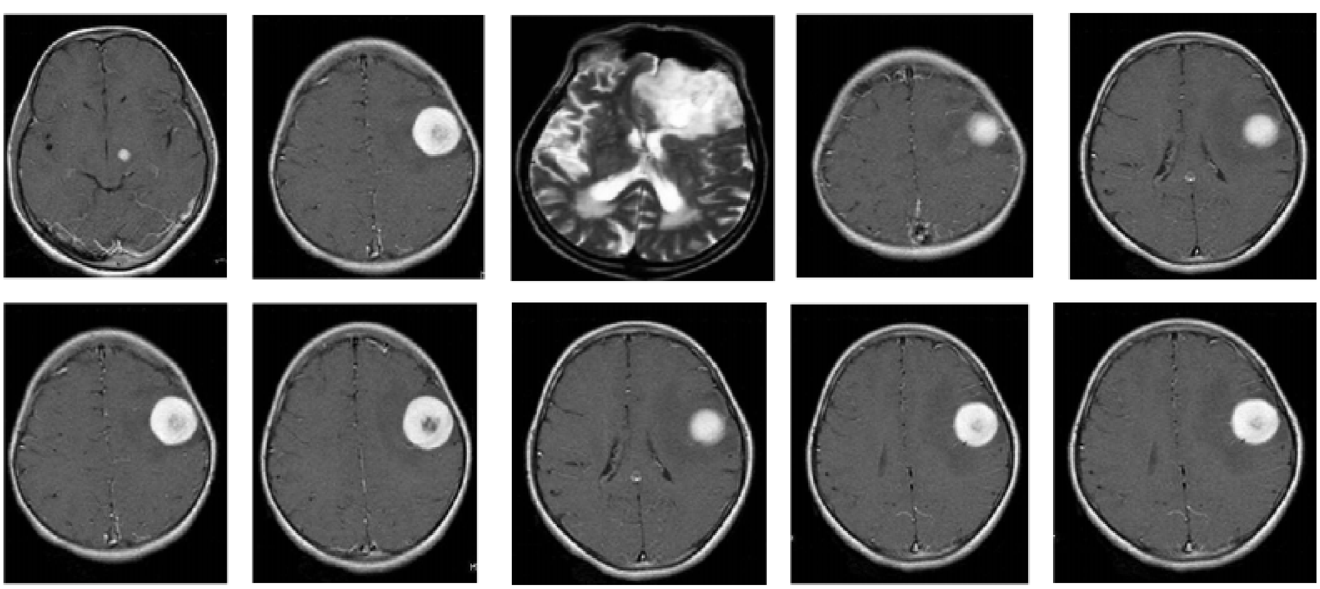


Fig. 10. Set of Sample Brain MRI Images.

TABLE II. INPUT AND SEGMENTED BRAIN TISSUE IMAGES

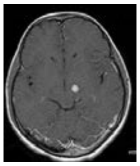
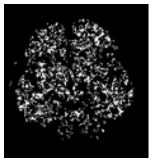
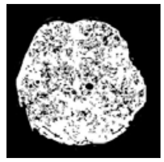
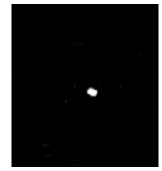
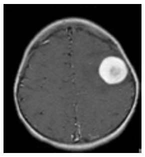
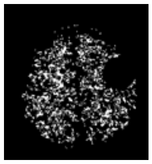
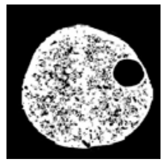
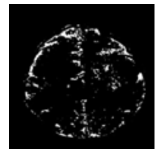
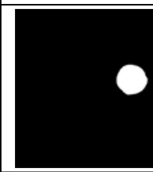
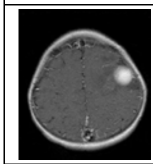
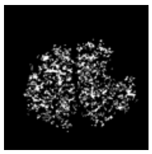
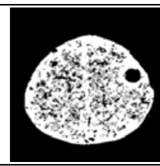
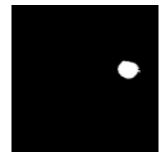
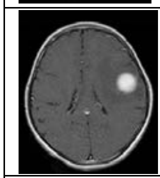
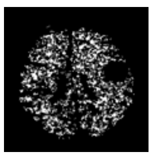
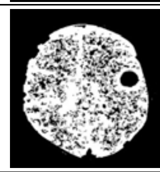
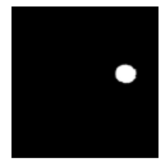
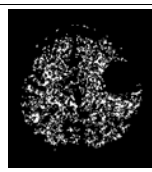
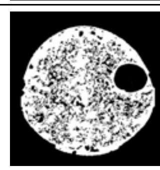
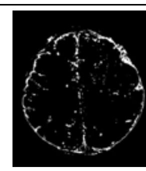
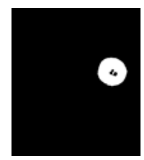
Input image	***WM***	***GM***	***CSF***	***TT***
				
				
				
				
				

TABLE III. COMPARATIVE ANALYSIS OF EXISTING AND PROPOSED IRFCM TECHNIQUE

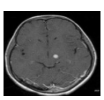
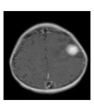
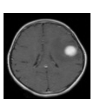
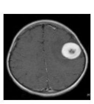
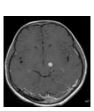
Input Image	**Class**	**Rough K-Means**			**Rough FCM**			**Improved RFCM**		
		Sensitivity	Specificity	Accuracy	Sensitivity	Specificity	Accuracy	Sensitivity	Specificity	Accuracy
	CSF	0.978	0.998	0.997	0.978	0.998	0.997	0.987	1.000	0.999
	GM	0.768	0.976	0.899	0.769	0.981	0.902	0.776	0.981	0.905
	WM	0.938	0.985	0.980	0.938	0.985	0.981	0.947	0.988	0.984
	TT	0.990	1.000	1.000	0.990	1.000	1.000	1.000	1.000	1.000
	CSF	0.989	0.998	0.998	0.989	0.998	0.998	0.999	1.000	1.000
	GM	0.799	0.990	0.911	0.799	0.990	0.911	0.806	0.990	0.914
	WM	0.943	0.984	0.979	0.943	0.984	0.979	0.952	0.987	0.983
	TT	0.987	1.000	1.000	0.987	1.000	1.000	0.997	1.000	1.000
	CSF	0.970	0.998	0.996	0.970	0.998	0.997	0.980	1.000	0.999
	GM	0.774	0.963	0.889	0.774	0.969	0.893	0.782	0.969	0.896
	WM	0.936	0.982	0.978	0.936	0.982	0.978	0.945	0.986	0.982
	TT	0.989	1.000	1.000	0.989	1.000	1.000	1.000	1.000	1.000
	TT	0.990	0.999	0.998	0.990	0.999	0.998	1.000	1.000	1.000
	CSF	0.790	0.920	0.874	0.791	0.934	0.883	0.798	0.933	0.885
	GM	0.960	0.980	0.978	0.960	0.980	0.978	0.970	0.983	0.982
	WM	0.988	1.000	1.000	0.988	1.000	1.000	0.998	1.000	1.000
	TT	0.990	0.998	0.998	0.989	0.998	0.998	0.999	1.000	1.000
	CSF	0.827	0.979	0.918	0.827	0.979	0.918	0.835	0.979	0.921
	GM	0.939	0.986	0.980	0.939	0.986	0.980	0.948	0.989	0.985
	WM	0.987	1.000	1.000	0.987	1.000	1.000	0.997	1.000	1.000
	TT	0.978	0.998	0.997	0.978	0.998	0.997	0.987	1.000	0.999
Average of Tissues		0.927	0.987	0.969	0.927	0.988	0.970	0.936	0.989	0.972

Fig. 11 illustrates the average measure obtained by the proposed IRFCM and existing RFCM and RK-means techniques for FPR and FNR measures. In the proposed method, the MR image is initially segmented by Improved RFCM. Then successfully, the tissue parts of brain MR images are classified by choosing the parameters optimally. The proposed system is mainly developed for the association of brain images tissue identification.

Fig. 12 describes the segmentation outcome of different measures like sensitivity, specificity, accuracy, PPV and NPV for proposed and existing technique. Thus, the developed IRFCM method achieves the efficient result than existing techniques.

An input sample image is tested by the proposed approach in GUI representation is shown.

The Graphical User Interface (GUI) based sample output and taken input test image is demonstrated in Fig. 13. Since, the test image of input is uploaded, then it provides the classification and segmentation consequences in the display. Thus, this GUI linked proposed approach can shows the corresponding outputs even varying the input test image of different MRI brain pictures.

Fig. 14 and 15 is a GUI example for the different images given. The results of this are evaluated by changing the input image. The resultant values obtained by the evaluation metrics such as Specificity, Sensitivity, PPV, Accuracy, FPR NPV, and FNR for existing Default FIS, KNN and the proposed OFIS technique under a sample test images. By analyzing the performance metrics, the sensitivity of proposed methodology is 0.95, accuracy is 0.975, PPV is 0.95 which is more superior than other existing techniques. Similarly, NPV, FPR and FNR give better performance for proposed technique than existing techniques.

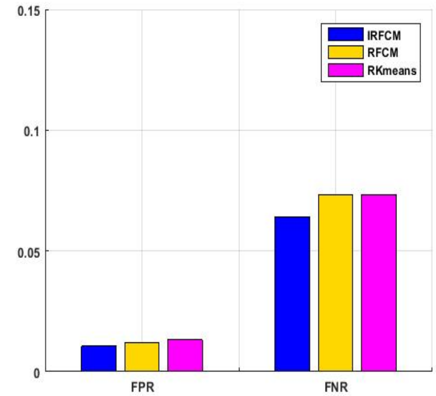


Fig. 11. Segmentation Result for FPR and FNR.

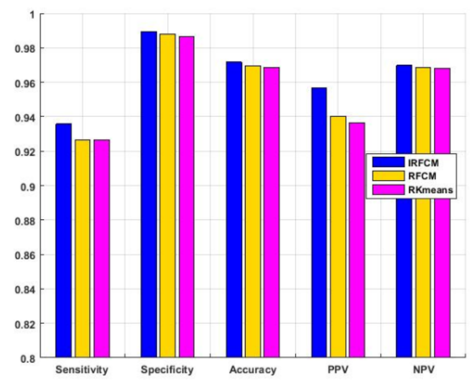


Fig. 12. Evaluation Metrics Segmentation Result.

Fig. 13. Sample GUI Representation for Brain Tissue Classification.

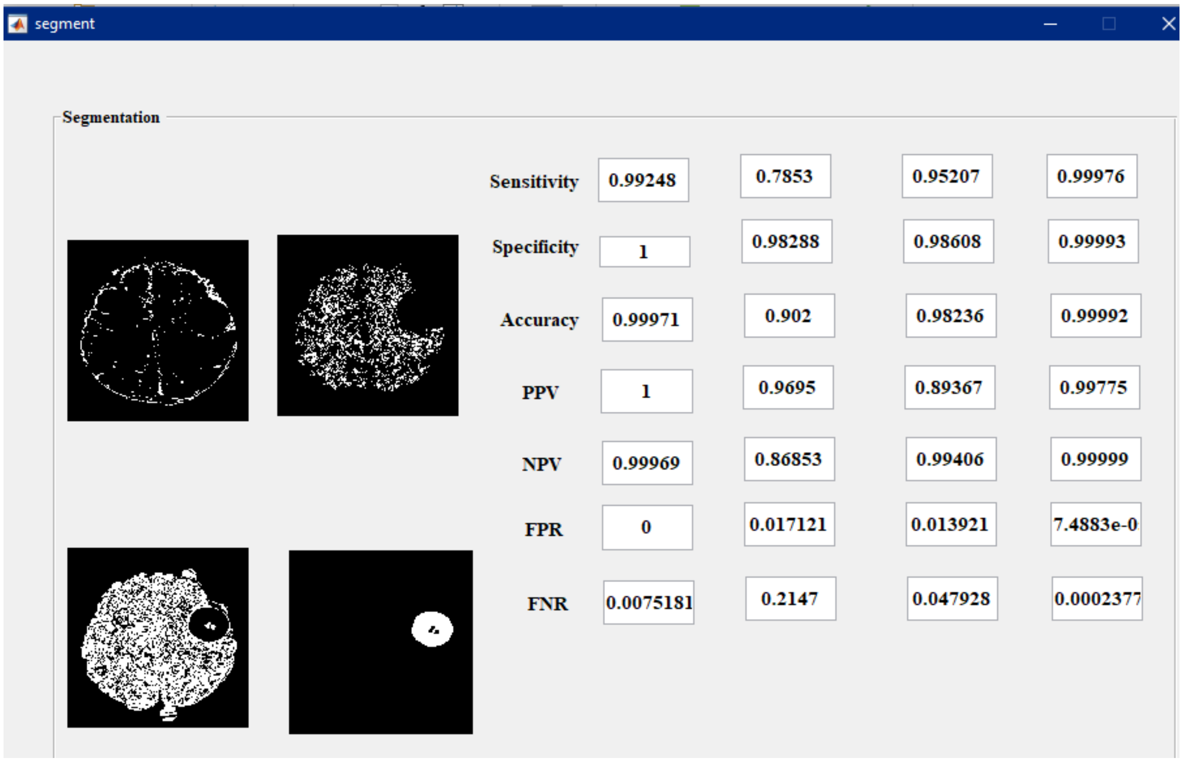
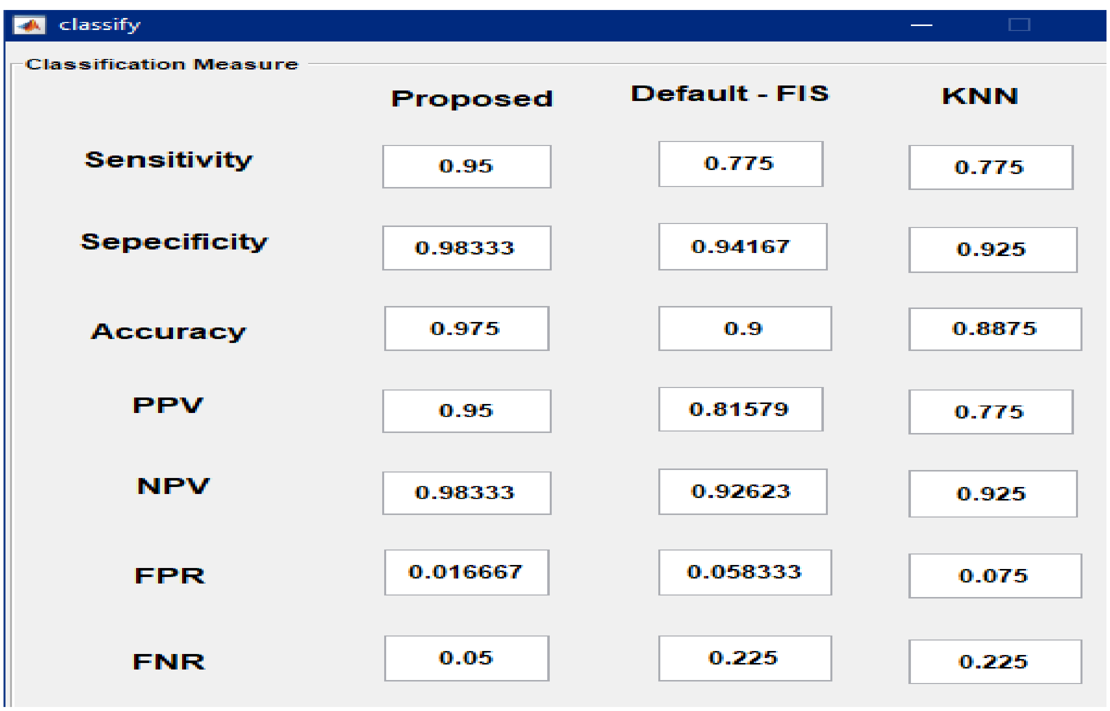


Fig. 14. Segmented MRI Images and its Performance Metrics.



classify

Classification Measure

	Proposed	Default - FIS	KNN
Sensitivity	0.95	0.775	0.775
Sepecificity	0.98333	0.94167	0.925
Accuracy	0.975	0.9	0.8875
PPV	0.95	0.81579	0.775
NPV	0.98333	0.92623	0.925
FPR	0.016667	0.058333	0.075
FNR	0.05	0.225	0.225

Fig. 15. Performance Metrics Rates for Proposed and Existing System.

TABLE IV. COMPARISON BETWEEN PROPOSED AND EXISTING METHODS FOR DIFFERENT METRICS

Evaluation metrics	KNN	FIS	*Proposed OFIS*
PPV	0.77	0.81	0.95
NPV	0.925	0.926	0.98
FPR	0.075	0.058	0.01
FNR	0.225	0.225	0.05

The obtained experimental results of the MRI images for the proposed OFIS and different existing technique for metrics PPV, FPR, NPV, and FNR are shown in Table IV. Thus, the comparative analysis from the graph shows that the proposed technique function is significantly enhanced, which is finest for identifying the portion of tissues in brain MRI images.

VII. CONCLUSION

Brain tissue classifications are the foremost challenging feature in the diagnosis of diseases via medical images. In this work, an efficient approach is proposed to identify the type of brain tissue of MR images. To this classification, primarily, the input of MRI brain image is pre-processed by speckle noise removal method to eliminate the noisy contents contemporaneous in the input image. The pre-processed image is then segmented using an Improved RFCM algorithm based on the clustering mechanism. Next to this, significant texture features are alone extracted by the use of the GLCM feature extraction technique. Afterward, the features were extracted from the previous function are fed into the stage of classification. In that place, OFIS is applied to classify images as WM, GM, CSF, BG, and TT. In OFIS, its parameter is optimally chosen via EGOA for optimally classifying brain tissue. The whole work is executed in the working of MATLAB® platform. The performance of the developed model is analyzed by the evaluation metrics to differentiate the developed and conventional approaches. The complete analysis shows that it is clear that the proposed technique accomplishes an efficient outcome over existing techniques. In future work, the extra information can be added to improve the system as more sensitive; the data for the analysis will consider from the location or textures. In addition to this, future work can be focused on the pathological investigations of classification with the basic goals of monitoring as well as locating the lesions in tissues of the brain.

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Empirical Validation of WebQMDW Model for Quality-based External Web Data Source Incorporation in a Data Warehouse

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***Abstract*—In recent years, World Wide Web has emerged as the most promising external data source for organizations' Data Warehouses for valuable insights required in comprehensive decision making to gain a competitive edge. However, when the Data Warehouse uses external data sources from the Web without quality evaluation, it can adversely impact its quality. Quality models have been proposed in the research literature to evaluate and select Web Data sources for their integration in a Data Warehouse. However, these models are only conceptually proposed and not empirically validated. Therefore, in this paper, the authors present the empirical validation conducted on a set of 57 subjects to thoroughly validate the set of 22 quality factors and the initial structure of the multi-level, multi-dimensional WebQMDW quality model. The validated and restructured WebQMDW model thus obtained can significantly enhance the decision-making in the DW by selecting high-quality Web Data Sources.**

***Keywords*—Data warehouse; external data sources; web data sources; quality evaluation model; quality model validation**

I. Introduction

The importance of incorporating external data in the Data Warehouse to gain valuable insights into the market, competitors, products, or customers for comprehensive and unbiased decision making, has been long recognized in the research literature [1], [2]. The use of World Wide Web (WWW or Web) [3] as an external data source for the Data Warehouse (DW) [4] has grown considerably over the past few years [5]–[16]. The WWW helps provide a wide-angle lens for the decision-making in organizations in a very low-cost and highly accessible manner [4] (see Fig. 1). It is a known fact that the quality of the DW data sources hugely impacts the quality of the DW itself [1], [2]. This fact makes the quality-aware evaluation and selection of high quality, credible, and compatible Web Data Sources (WDSs) a very crucial task in the incorporation of Web data in the DW [4], [17]–[27]. There are, however, many challenges in this task like the availability of a massive amount of information, the heterogeneous structure and format of the Web Data [4], the dynamic nature [17], and poor reliability [18] of a significant chunk of Web Sources.

For the aforementioned task of quality-aware evaluation of Web Data Sources for a Data Warehouse, various quality models, frameworks, or a set of factors have been proposed in the research literature (see, for example, [19], [22]–[24],[4], [21], [20], [25], [26]). However, these quality models are only conceptual in nature. To the best of the authors' knowledge, none of these quality evaluation models for evaluating WDSs as external data sources for a DW have been empirically validated to corroborate their applicability in this problem area. In order to fill this research gap, in this paper, we present the empirical validation of the state-of-the-art multi-level, multi-dimensional WebQMDW (Web quality model for evaluating web sources for the DW) quality model [27] to enhance the decision making in a Data Warehouse. WebQMDW model [27] is the first of its kind model which segregates the quality factors in such a way to introduce automated quality evaluation as screening (at the first level) and separation of expert evaluation of different expert areas into different dimensions (at the second level). The present work complements and extends the authors' previous work [27] of the quality-based evaluation of the websites of academic institutions for incorporation as WDSs in a University DW. The said work proposed and used the novel $WSEM_{QT}$ (Web source evaluation with multi-criteria decision-making methods and web quality testing tools) process in conjunction with the underlying novel WebQMDW quality model. We believe that the empirical validation of the WebQMDW model will be an important milestone in the quality evaluation of WDSs for a DW, aiding the DW professionals in providing advanced data analytics for decision-making in the organization.

Hence, the objective of this paper is the empirical evaluation of the WebQMDW model in order to

- Validate the set of quality factors of the WebQMDW model; and eliminate or add new factors, if indicated by the validation results.
- Validate that the quality factors have been suitably placed in the level/dimension of the WebQMDW model; or if they should be placed in a different level/dimension according to the validation results.

The rest of the paper's overall arrangement is as follows: Section II discusses the frame of reference of the current work, including the related work, WebQMDW quality model, and motivation. Section III presents the empirical validation process of the WebQMDW model, including the analysis of results and restructuring of the model. Section IV discusses the various threats to the validity of the survey and how we dealt with them, followed by conclusion and future work in Section V.

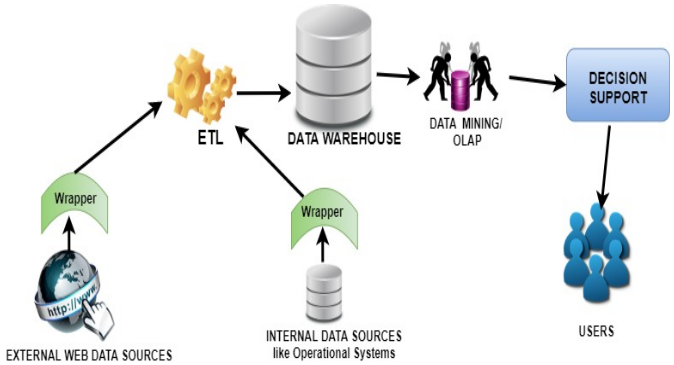


Fig. 1. Web Data as External Data Source for a Data Warehouse.

II. Frame of Reference

A. Related Work and the WebQMDW Quality Model

Quality is a critical and hence, widely researched concept in the context of both software products and data. From the point of view of Data/Information Quality (DQ/IQ), there are established standards (like ISO/IEC 25010/25012 [28], [29]) as well as "de facto" standards (like the Wang and Strong model [30]) in the relevant literature. Due to the peculiar characteristics of Web portals as opposed to a traditional software product, a plethora of research works have specifically addressed the Website/Web portal quality [31]–[33]. The quality evaluation of WDSs for a DW, however, encompasses the data quality as well as the source Website quality because due attention needs to be given to the quality requirements specific to the destination of the WDS incorporation, i.e., the Data Warehouse and the underlying business domain as well [27]. Few of the important works in the area of defining quality factors/models for using the WDSs as EDS for the DW are summarized in Table I. Huang et al. [4] have suggested integrating Web Data in a DW by considering both Quality and Coverage aspects. Quality aspect evaluation is proposed by using quality factors of Speed of loading, Accuracy, Currency, Presentation, Format, Content, and Source as put forward by Rieh [33]. Coverage aspect evaluation is proposed by determining two factors of Scope and Variety. Lóscio et al. [20] have used the three quality parameters of Data Completeness, Schema Completeness, and Correctness for determining the relevance of a WDS for a particular application domain. For a quality-aware Web Warehouse, Marotta et al. have proposed managing Data and Service Quality in their work [21]. In this work, the organization of Data quality is in six dimensions: Reliability, Consistency, Uniqueness, Freshness, Completeness, and Accuracy [21]; Whereas the organization of Service-Related quality is in six dimensions of Stability, Usability, Business Value, Security, Interoperability, and Service Level. The WebQM quality model proposed by Zhu and Buchman [19] has three classes of Web Source Stability, Web Application Specific Quality, and Web Information Quality, used to group the twelve quality factors in this model. These quality factors are Timeliness, Presentation, Relevance, Metadata, Objectivity, Completeness, Correctness, Origin, Refresh Rate, Durability, Accessibility, and Availability [19]. For WDS quality, Mihaila et al. have used the four quality factors: Granularity, Frequency of Updates, Recency, and Completeness. [25]. Naumann et al. used the three quality factors of Availability, Extent, and Understandability in their work [26].

In a previous work, authors have proposed the WebQMDW quality model [27] with 22 quality factors classified in 2 levels (Fig. 2). At Level-1(Automated quality testing level), those quality factors based on which the overall quality of the Website/Webpage can be assessed by using the available website quality testing automated tools are placed. This level has seven quality factors: Performance, Accessibility, Domain Reliability, SEO (Search Engine Optimization), Security, Best Practices, and Web Search Engine Ranking. At Level-2(Expert evaluation level), fifteen quality factors according to which the experts need to evaluate the WDSs are allocated. This level is further divided into three dimensions based on the expert area required for judging them. Dimension 1, with Web Data Related Quality Factors, has five quality factors: Interoperability, Media Format, Cost of Access, Amount of Data, and Timeliness. A Web Data expert evaluates them. Dimension 2, with Data Warehouse Context-related Quality Factors, has five quality factors: Metadata interpretability, Time Period Correspondence, Concise Representation, Consistent Representation, and Completeness. A DW expert evaluates them. Dimension 3, with Business Domain related Quality Factors, has five quality factors: Business Value Addition, Accuracy, Objectivity, Believability, and Uniqueness. A Business Domain Expert evaluates them. In the current work, we choose to focus on this model as the selection and structuring of quality factors is in such a way that it solves the two main issues of the quality evaluation process of Web data sources [27]. The first issue of an enormous load of evaluation on experts is tackled due to the screening of the vast number of web sources to a select few through automated Website quality testing tools at the 1st level of the model. The second issue in previous quality models was the bottleneck of finding experts with expertise in all the related domains of quality evaluation. This issue is also resolved at the 2nd level of the model as different experts need to evaluate the quality factors separated into different dimensions according to the required expertise, namely Web, Data Warehouse, and underlying business domain. The initial structure of the WebQMDW model is shown in Fig. 2. The details of these 22 quality factors in the context of the Web Source Quality evaluation and the detailed account of the model's application to a practical case study of a University DW can be found in [27].

TABLE I. SUMMARY OF SOME WORKS DEFINING QUALITY MODELS FOR QUALITY-BASED EVALUATION OF WDSS FOR DW

Author(s)	Domain	Structure of quality model/ framework	Whether empirically validated? (Yes/No)
Huang et al. [4]	Quality of WDS for DW	2 dimensions; Total 9 QFs	No
Lóscio et al. [20]	Web Data Source quality	Total 3 QFs	No
Marotta et al. [21]	Quality-aware Web Warehouse	2 categories; Total 12 QFs	No
Zhu and Buchman [19]	Quality of WDS for DW	3 categories; Total 12 QFs	No
Mihaila et al. [25]	WWW Source selection	Total 4 QFs	No
Naumann et al. [26]	Quality driven Web Source selection	3 dimensions; Total 3 QFs	No
Bhutani et.al [27]	Quality of WDS for DW	2 levels, 3 dimensions; Total 22 QFs	No

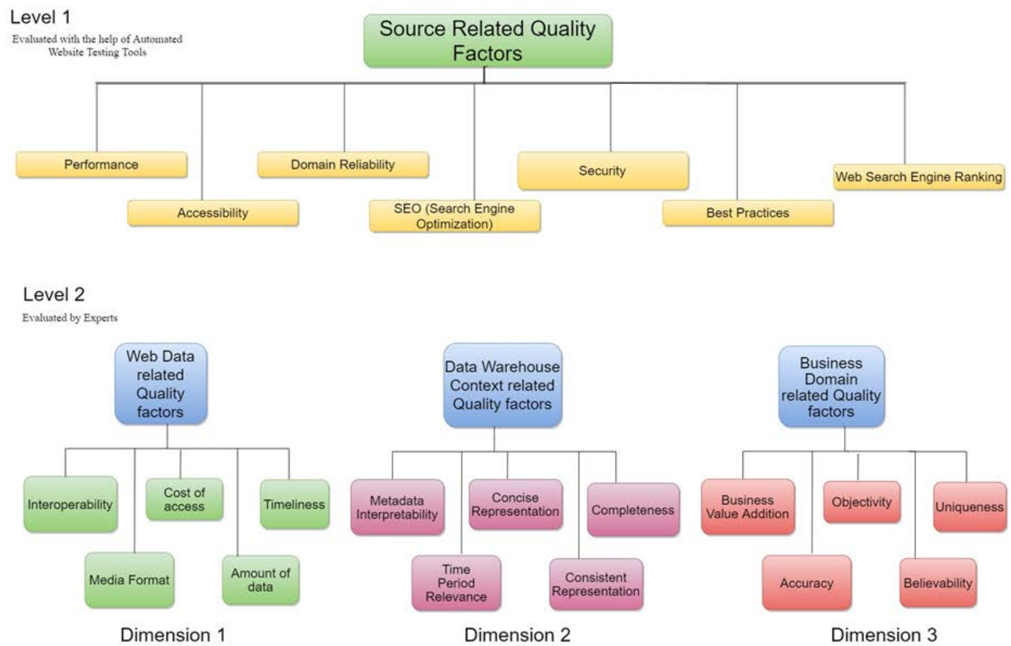


Fig. 2. WebQMDW- a Quality Evaluation Model for Web Data Sources as EDS of a DW [36].

B. Motivation

For any area, after proposing the quality model, the next step is its validation from the perspective of the users of the respective domain. The validation is important due to two reasons. Firstly, it is essential to consider users' choices of quality factors due to their profile, experience, and knowledge in the respective field [34]. Secondly, the robust statistical analysis from the empirical validation attaches confidence to the adequacy of the proposed quality model [35].

In the area of generic quality evaluation of Websites, there are several empirical validations works in the research literature (Table II). The work of Caro et al. [32] validates a quality model for evaluation of the quality of Websites. The research work [36] of Moraga et al. validates a quality model for website quality specifically from the point of view of "University-educated users." A quality model for evaluating health websites' data quality is validated through experts in the work of Liete et al. [35]. Some authors [32], [36] have performed the validation using the survey method. Few authors have used the Delphi method [37] for the validation of the quality models [35].

However, no such validation works of quality models specific to the context of evaluation of WDSs as EDS to a DW (see Table I) could be found in the research literature, to the best of the authors' knowledge and belief. Hence, the current work provides the validation of the WebQMDW model (described in the previous section), which is specific for the said context [27]. It is performed by using the survey method according to the guidelines of the work of Pfleeger and Kitchenham[38]–[43], as described in the subsequent sections (see Sections III and IV).

TABLE II. SUMMARY OF SOME RELATED WORKS DEFINING/ VALIDATING QUALITY MODELS FOR EVALUATION OF WEBSITES

Author(s)	Domain	Structure of quality model/ framework	Whether Validated? (Yes/No)
Caro et al. [32]	Web Portal Quality	4 categories; Total 33 QFs	Yes
Moraga et al. [36]	Web Portal Quality	4 categories; Total 42 QFs	Yes
Liete et al. [35]	Health UnitWebsites' Quality	3 categories; Total 23 QFs	Yes

III. Validation Process of the WebQMDW Model

As described in the previous section, the WebQMDW model has been obtained by bearing in mind the definitions of the quality factors and the defined categories (i.e., levels/dimensions) identified for structuring the factors. This section elaborates the validation process of both the set of quality factors and the initial hierarchical structure of the WebQMDW model.

A. Research Methodology

Several empirical validation methods [44] are described in the research literature, like case studies, controlled experiments, ethnographies, and surveys. The survey method [38]–[44] has a defining characteristic of studying the applicability of the phenomenon on the target population by polling the survey questionnaire on the representative subset of the target population. Bearing in mind that we need to study the applicability of the WebQMDW model in the opinion of the Web and Data Warehouse users (the target population), this was the best applicable method for our work. So, in this paper, we use the survey method as the validation method to thoroughly validate the set of quality factors and the structure of the WebQMDW model while following the guidelines and principles of research proposed by Kitchenham and Pfleeger [38]–[43]. These guidelines describe the various activities for collecting information for describing, comparing, or explaining knowledge, behavior, and attitudes, by using the survey instrument [43].

B. Setting of Objectives

Measurable and specific objectives are set in this step. We set the main objective of our survey as: ‘‘To acquire the viewpoint of Web and Data Warehouse users regarding the importance as well as the placement (in the levels/dimensions) of each of the quality factors in the WebQMDW model.”

C. Selection of Subjects

Keeping the objective mentioned earlier in mind, the target subjects required were both Web and Data Warehouse users. For the purpose of empirical analysis, many researchers have pointed out the advantages of taking students as subjects [45], [46] as the students’ knowledge tends to be homogenous and a high number of students as subjects are conveniently available simultaneously. According to us, the students who have the knowledge and practical hands-on experience of Data Warehouse and the World Wide Web were well suited to be this survey’s subjects. Additionally, if the students have the knowledge of Data and Software Quality, they will be able to assess the importance of each quality factor better. Hence, it was decided to use “Convenience sampling” and administer the survey to a set of students, the 74 students of the Data Warehousing & Mining Course of the final-year class of Information Technology program at USIC&T, GGSIP University, New Delhi, India. These students not only had knowledge of the Web and Data Warehouse but had also studied an entire course on Software Engineering as part of their curriculum previously. The survey was conducted as a part of the mandatory practical laboratory session of the Data Warehousing & Mining course. Therefore, there was enough motivation in the students to be a part of the survey.

D. Selection of the Design of the Survey

The descriptive design of the survey is considered most appropriate, where the objective requires a description of the phenomenon of interest. The objective of this survey requires a description of the opinion of the respondents regarding the importance and placement of quality factors in the WebQMDW model. Hence, the descriptive design [38] was considered appropriate and selected by us rather than the experimental design.

E. Preparation of the Survey Instrument

The guidelines of designing the survey instrument, i.e., the questionnaire [39], suggest that the survey questions should be chosen, keeping in mind the objective of the survey. Hence, in accordance with the objective mentioned earlier, we constructed the questionnaire with 22 Likert-style closed questions divided into sections I and II, asking the importance of the 22 quality factors of WebQMDW model Level I and Level II, respectively (Fig. 3, Fig. 4). Only the naming of quality factors in the questions could have led to ambiguity in the respondents' minds about the meaning of the quality factors. So, we formulated the questions in conventional simple English language by adapting the definition of each factor from the research literature [27], [32]. The answers to the closed questions were supposed to be marked in the 5-point Likert scale ranging from the lowest score ‘1’ signifying ‘Not Important’ and highest score ‘5’ signifying ‘Very Important.’ Section III consisted of 2 open questions regarding the structural placement of quality factors in the levels/dimensions of the WebQMDW model (Fig. 5). The first open question focused on any suggested switching of the category (i.e., Level/Dimension) of the factors in the WebQMDW model. The second open question focused on any other quality aspect or factor to be added to the WebQMDW model.

Section- I (corresponding to importance of WebQMDW Level 1 quality factors)

Level 1

Q.1 The importance value of the Performance i.e the Speed of loading of the Web Source, should be:

Q.2 The importance value of the Web Source having proper navigation mechanisms to be accessed speedily and with ease, should be:

Q.3 The importance value of the Web Source domain being considered trustworthy and delivering appropriate data, should be:

Q.4 The importance value of the Web Source having a strong SEO (Search Engine Optimization) for the relevant data to be discovered easily, should be:

Q.5 The importance value of the Web Source having security provisions (like SSL certificate) for preventing manipulation and unauthorized access to data, should be:

Q.6 The importance value of the various Best Practices that are followed by the Web Source (e.g practice of deferring download of unnecessary resources), should be:

Q.7 The importance value of the Web Source having high popularity and being considered worthy of great reputation for its content and services, should be:

Fig. 3. Survey Questionnaire -Section I (Reproduction of Questions from the Google form Questionnaire).

Section- II (corresponding to importance of WebQMDW Level 2 quality factors)

Level 2, Dimension 1
Q.8 The importance value of the Web Source data having the ability to be accessible over different platforms (operating systems or hardware architecture), should be:
Q.9 The importance value of the media format (text/HTML/pdf/audio/video etc) of the data from the Web Source fitting within the processing ability of the organization, should be:
Q.10 The importance value of the degree to which the data from the Web source is worthy of the cost associated (if it requires access fees), should be:
Q.11 The importance value of the amount or quantity of data provided by the Web Source being significant, should be:
Q.12 The importance value of the Web Source providing the data within the time constraint specified by the need of organization, should be:

Level 2, Dimension 2:
Q.13 The importance value of the description or metadata of the data from the Web Source being easy to interpret in accordance with the Data Warehouse schema, should be:
Q.14 The importance value of the data from the Web Source corresponding to the required time period according to the usage of Web data in Data Warehouse, should be:
Q.15 The importance value of the data from the Web Source being concise and free of superfluous elements that are not required for the right purpose in the Data Warehouse, should be:
Q.16 The importance value of the data from the Web Source being consistently represented in same or compatible formats throughout the Web pages of the Web Source, should be:
Q.17 The importance value of the data of the Web Source providing a complete coverage in terms of the depth, breadth and scope of the task at hand of the Data Warehouse, should be:

Level 2, Dimension 3:
Q.18 The importance value of the degree to which the data from Web Source is beneficial and adds value to the business of the organization, should be:
Q.19 The importance value of the data from the Web Source being correct and guaranteed to be error-free especially in the context of the application domain, should be:
Q.20 The importance value of the data from the Web Source being impartial and free from bias, should be:
Q.21 The importance value of the extent to which the data from the Web Source is believable, should be:

Fig. 4. Survey Questionnaire -Section II (Reproduction of Questions from the Google form Questionnaire).

Section- III (corresponding to open questions for structure of WebQMDW model)

Q.23 Do you suggest the switching of the category (i.e level or dimension in the WebQMDW quality model) of any quality factor?
Q.24 Do you suggest the addition of any new quality factor, not covered in the WebQMDW quality model?

Fig. 5. Survey Questionnaire – Section III (Reproduction of Questions from the Google form Questionnaire).

F. Validation of the Survey Instrument

We pre-tested the questionnaire to validate the survey instrument. Ten respondents (5 of them pursuing Ph.D. in the field of Data Warehousing and the rest 5 pursuing Ph.D. in the field of Web Engineering) answered the questionnaire before its actual administration. Following their feedback about the understanding of the questions, three questions (with questions no. 6, 9, and 10) were modified with examples and simpler language to improve the questionnaire.

G. Administration of Survey

The survey was administered to the subjects in an online session of a Data Warehousing & Mining laboratory class. The questionnaire was delivered in the form of a Google form whose link was shared with the subjects. Before the beginning of the session, the purpose and importance of the study were briefly explained to the respondents. The time limit of one hour for submitting the responses to the survey was also communicated to them.

H. Analysis of the Data

The survey was supposed to be administered to an expected sample of 74 subjects. In the actual scenario, the survey session was attended by 59 subjects because the remaining subjects were absent during the session. The recorded response rate was, hence, 79.7%. However, during the session, two subjects could not complete the survey due to network issues. So, the rest of the 57 responses were considered.

First, we analyzed the internal consistency of our data from closed questions with the help of Cronbach's alpha value (Equation 1) [47]. We determined Cronbach's alpha for data of section I and section II of the questionnaire, corresponding to importance value responses for quality factors from Level 1 and Level 2 of the WebQMDW model, respectively (see Table III). As a thumb rule, the value of Cronbach's alpha above 0.7 is considered acceptable. For our data, the values obtained were 0.889 for Section I and 0.920 for Section II. Hence, the survey can be said to have good internal consistency and reliable results for further analysis.

TABLE III. RESULTS OF CRONBACH'S ALPHA VALUE ANALYSIS

Questionnaire Data	Cronbach's Alpha Value
Section I (corresponding to Level 1 of WebQMDW model)	0.889
Section II (corresponding to Level 2 of WebQMDW model)	0.920

Cronbach's alpha [47] i.e., $\alpha = \frac{N \cdot \bar{c}}{\bar{v} + (N-1) \cdot \bar{c}}$ (1)

Where N= the number of items

$\bar{c}$= average inter-item covariance

$\bar{v}$= average variance

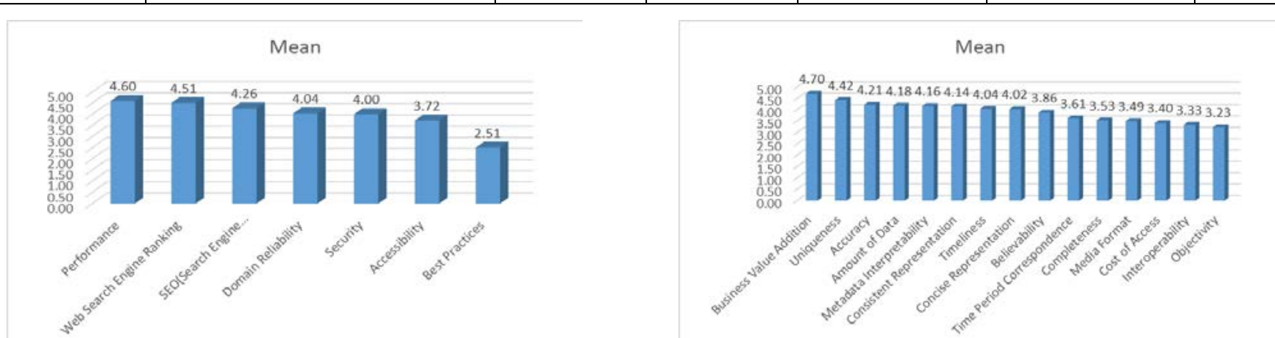
Tables IV and V shows the descriptive statistics of the responses for the importance values for the 22 quality factors. In this work, we have calculated the mean (i.e., average value) and the percentage coefficient of variation (%CV) of the importance values, to be used as the indicators for including or excluding the quality factors. It was decided to eliminate the factors whose mean value was below the value 3.0 (mid-point of the scale) as conceptually, in the view of the participants, they did not seem significant enough to be considered a quality factor for the evaluation of Web sources. We also decided to eliminate those quality factors for whom the percent variation coefficient was above 33% because conceptually, there was inconsistency in the participants' viewpoint about the importance of this quality factor. Thus, considering the ranked values of mean importance of factors in Fig. 6, most of the 22 factors of the WebQMDW model had a mean importance value above 3. These values signified that the respondents considered most of the factors to be having moderate or high importance. Among the highly important factors were Performance, Web Search Engine Ranking, Business Value Addition, and Uniqueness. However, the quality factor Best Practices was eliminated as its mean value fell below the decided indicator of 3.0. None of the factors had a percent variation coefficient of above 33%, so no factor was eliminated for this particular constraint (Fig. 7). The open question (number 23), which focused on any suggested switching of the category (i.e., level or dimension) of any quality factor, was not answered by any of the respondents. The last open question (number 24), which focused on the addition of any new quality factor, was answered by four participants who suggested including Reputation as one of the factors. On close review of meanings of the factors from the review of literature, it was seen that in the context of Web Sources, in particular, this factor of Reputation [30] was synonymous to the factor Web Search Engine Ranking that was already included in the WebQMDW model [27]. The factor name Reputation was also used in the pioneering work of Wang and Strong, considered a de-facto Data Quality standard [30]. So, instead of adding another factor, we decided to consider renaming the factor Web Search Engine Ranking to the more general name of Reputation.

TABLE IV. DESCRIPTIVE STATISTICAL ANALYSIS OF EACH QUALITY FACTOR OF LEVEL 1

Quality Factor	Min. Value	Max. Value	Mean Value	Standard Deviation	%CV
Performance	3	5	4.60	0.53	14.50%
Accessibility	2	5	3.72	0.80	21.41%
Domain Reliability	3	5	4.04	0.57	14.02%
SEO (Search Engine Optimization)	2	5	4.60	0.77	18.02%
Security	3	5	4.00	0.46	11.57%
Best Practices	1	4	2.51	0.71	28.31%
Web Search Engine Ranking	2	5	4.51	0.68	15.18%

TABLE V. DESCRIPTIVE STATISTICAL ANALYSIS OF EACH QUALITY FACTOR OF LEVEL 2

Dimension	Quality Factor	Min. Value	Max. Value	Mean Value	Standard Deviation	%CV
Dimension 1	Interoperability	3	4	3.33	0.48	14.27
	Media Format	3	4	3.49	0.50	14.45
	Cost of Access	2	5	3.40	0.80	23.47
	Amount of Data	2	5	4.18	0.87	20.80
	Timeliness	3	5	4.04	0.42	10.44
Dimension 2	Metadata Interpretability	3	5	4.16	0.53	12.69
	Time Period Correspondence	2	5	3.61	0.70	19.39
	Concise Representation	3	5	4.02	0.52	12.87
	Consistent Representation	2	5	4.14	0.81	19.60
	Completeness	3	5	3.53	0.54	15.26
Dimension 3	Business Value Addition	2	5	4.70	0.60	12.69
	Accuracy	3	5	4.21	0.80	18.90
	Objectivity	1	4	3.23	0.68	21.12
	Believability	2	5	3.86	0.91	23.70
	Uniqueness	2	5	4.42	0.71	15.96



(a) (b)

Fig. 6. Ranked Quality Factors of WebQMDW Model According to Mean of Importance Values (a) Level-1 (b) Level-2.

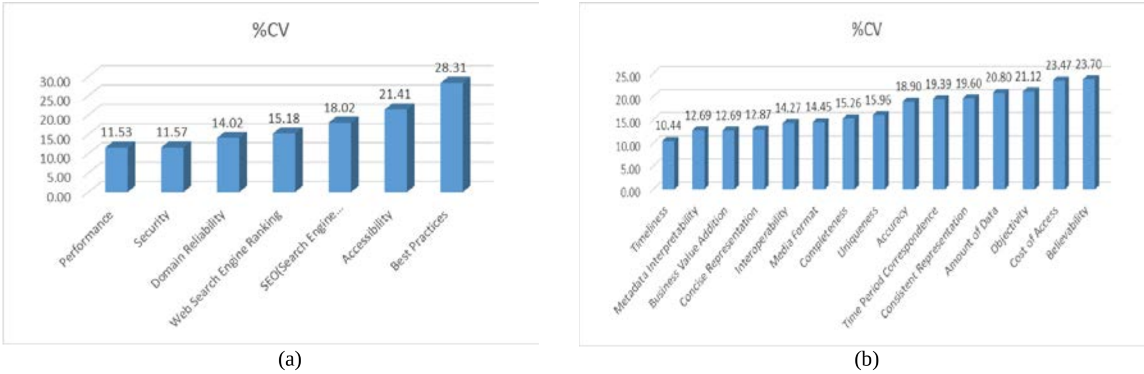


Fig. 7. Ranked Quality Factors of WebQMDW Model According to Percent Coefficient of Variation (%CV) of Importance Values (a) Level-1 (b) Level-2.

I. Restructuring of the Quality Factors of the WebQMDW Model

The initial structure of the WebQMDW model is shown in Fig. 1. After completing the above-stated validation process, the WebQMDW model now consists of a set of 21 factors, instead of 22, as one of the factors Best Practices was eliminated in the validation. As stated above, the factor Web Search Engine Ranking was renamed as Reputation. Since none of the participants suggested switching of the categories (i.e., level/dimension) of the factors, no other restructuring was done. The final structure of the WebQMDW model (with the above-stated changes) is as shown in Fig. 8.

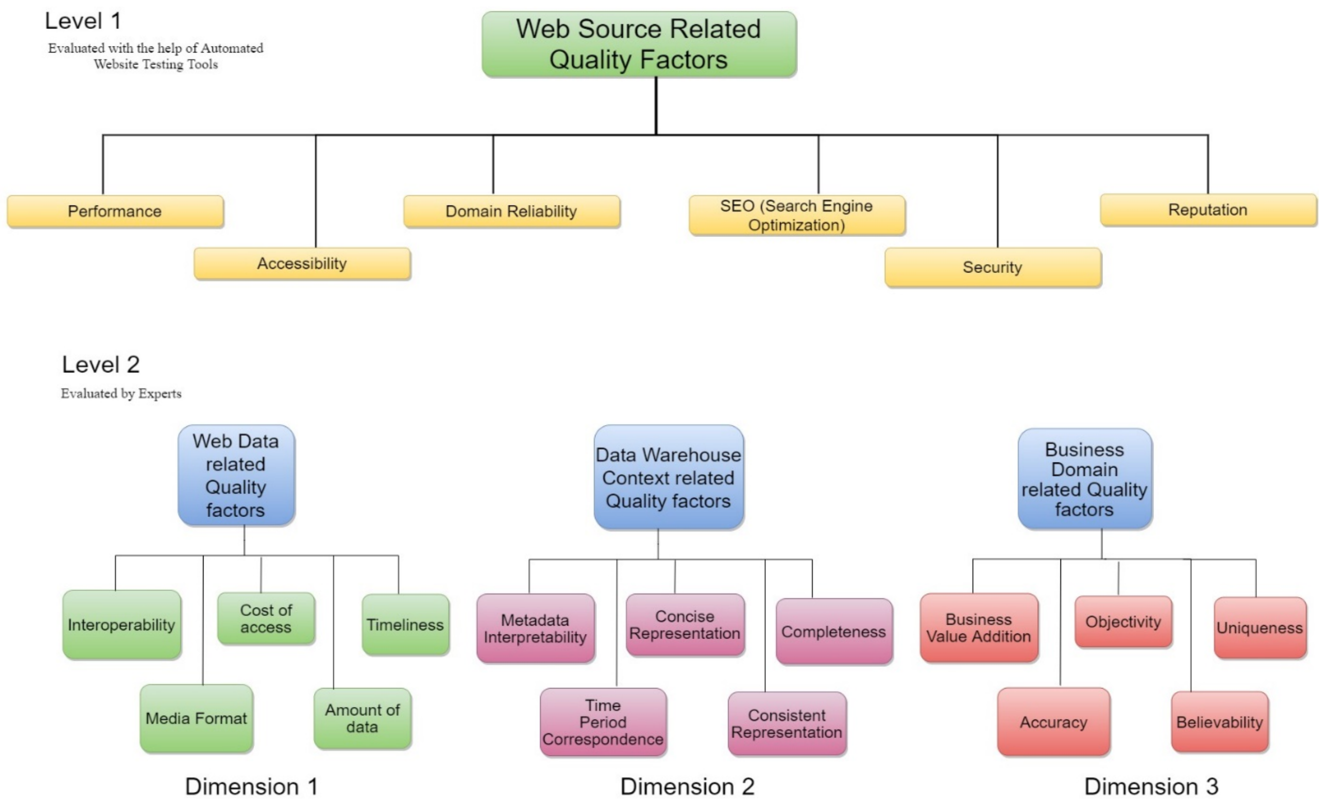


Fig. 8. Restructured WebQMDW Model- after the Validation Process.

IV. Threats to Validity

This section discusses the threats to the following kinds of validity and also how they were minimized:

A. Construct Validity

The survey uses the 5-point Likert scale to gather the opinion of the participants about the importance of the factors, with the lowest numerical value ‘1’ signifying ‘Not Important’ and the highest value ‘5’ signifying ‘Very Important.’ The Likert scale is used in many previous similar studies [32], [35] to gather the opinion of participants. This scale is an efficient tool for observation and hence, can be considered as a valid construct.

B. Internal Validity

To ensure internal validity is to make sure that the results are not being derived from casual relationships. For this aspect, we considered the following issues carefully:

- The students enrolled in the same class of Data Warehousing & Mining were taken as subjects. The subjects had adequate knowledge of Data and Software Quality as they had also studied an entire course on Software Engineering as part of their curriculum. Hence, it can be said that all the subjects had the same profile and level of experience both in Data Warehousing and Data Quality. Thus, the variability among subjects was reduced.
- Since the subjects had not taken part in any survey on the same lines as the present one, so the persistence effect was nullified.
- Since the survey was provided to be filled only once, so no learning could have taken place. Thus, the threat of the learning effect was not present.
- The survey was administered in a one-hour session. This time was much less than even one practical laboratory session time of the students. Hence, the fatigue effect was not that relevant in this case.
- The survey was conducted as part and parcel of the ongoing practical laboratory sessions of the subjects’ Data Warehousing & Mining course. The subjects were also motivated by telling them the importance of their contribution to the current research in the Data Warehousing field. Also, since subjects had already studied Web Warehousing as one of the advanced topics in the course, they showed sufficient interest in participating. Hence, we had achieved sufficient subject motivation for the survey.
- Since the survey was conducted in an online session with the subjects participating from their homes, their influence on each other was, if at all, very minimal. Further, to avoid plagiarism, it was ensured that the subjects kept their videos on during the entire one-hour session and were informed not to communicate with each other.

C. External Validity

External validity is the degree of generalizability of the research results to the population of interest and beyond in actual practice. External validity was ensured by mitigating the following two issues:

- Material and task used: A survey questionnaire structured as a Google form was the material used. This survey was independent as no previous task was needed to be done in order to fill it.
- Subjects: The students were used as subjects of this survey due to two major reasons. Firstly, the students clearly represented the population understudy for the survey as they had experience as Data Warehouse users as well as Web Portal users, along with the knowledge of Data Quality. Secondly, many researchers have argued in favor of using students as subjects [45], [46] without impacting the external validity much. However, we do not rule out the possibility of conducting a replicated study with experts from the industry in the near future.

D. Conclusion Validity

Conclusion validity is the statistical validity of the conclusion of the research. For this concern, the size of the sample (57 subjects) could be the only issue. However, most of the quality factors identified from the research literature have been previously used and mostly validated, in the sub-areas of the current problem domain, like Web Portal quality and Data Warehouse quality. Hence, the concern is subjugated. We will still consider conducting a replication study with a larger number of subjects from the industry.

V. Conclusion and Future Work

Over the last few decades, Web Data Sources have established their position as good, viable, and highly accessible External Data Sources for a Data Warehouse. However, the assessment of the quality of the Web Data Source is critical before their incorporation in the DW. Some quality models have been conceptually proposed in the research literature. However, to the best of the authors’ knowledge, none of the previously known models for the Web Data Source evaluation for a Data Warehouse have been empirically validated. Hence, this paper presents the validation process of the multi-level, multi-dimensional WebQMDW model for quality evaluation of Web data sources for a Data Warehouse. The objective was to provide an empirically validated quality model which will guide the DW professionals to provide enhanced decision making in the Data Warehouse by quality-based incorporation of external Web data sources. The thorough empirical validation is carried out through a survey based on the Pfleeger and Kitchenham work guidelines, which are considered a de-facto standard. A questionnaire with three sections was used as the instrument for the survey. Sections I and II correspond to the importance values of the quality factors from level 1(automated quality evaluation) and level 2(expert evaluation) of the WebQMDW model. Section III focuses on the structuring of the model into levels and dimensions. The statistical analysis of the results obtained from the validation survey revealed that 21 factors of the WebQMDW model are considered to be having either high or moderate importance for Web Source quality evaluation. The restructured and validated WebQMDW was obtained as suggested by the results of the empirical validation and supported by the research literature, which can be considered a significant contribution in this area. We plan to conduct a further study with a larger number of subjects, especially from the industry, in the near future. Such a study could be beneficial to refine the model further. We also plan to work on the measures for each quality factor and the refining of the granularity of the model.

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Correlating Discriminative Quality Factors (CDQF) for Optimal Resource Scheduling in Cloud Networks

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***Abstract*—The Correlating Discriminative Quality Factors (CDQF) for Optimal Resource Scheduling in cloud networks has been addressed in this manuscript. It is since the resources under the cloud platform are loosely coupled according to the SLA between the cloud platform and the resource partakers. This enables the possibility of multiple resources from diversified partakers, those intended to accomplish similar services. The resource scheduling intends to select one resource among available resources to accomplish the scheduled task(s). The contemporary contributions related to resource scheduling are specific to traditional QoS factors, including cost, deadline constraints, and power consumption. However, the quality of service is often influenced by the contextual factors of the IAAS. Hence, this manuscript portrayed a novel resource scheduling strategy that orders the resources under the degree of optimality proposed in this manuscript. Unlike traditional resource scheduling methods, this manuscript portrayed a set of context-related factors that are further used to define the heuristic measure called "Degree of Optimality." The experimental study on the simulated environment elevates the proposal performance advantage as opposed to other existing methods.**

Keywords*—*Resource management (RM); resource scheduling (RS); resource provisioning (RP); QoS; infrastructure-as-a-service (IAAS)

I. INTRODUCTION

With the increased number of digital resources deployment on the networked cloud systems, the corresponding resource optimization scheduling mechanisms with higher levels of quality factors have a significant impact on the consumers' community and the providers' community of Cloud platforms. Nowadays, almost all organizations are leveraging Cloud computing capabilities to minimize their ownership cost and improve the productivity of their employees. Optimal resource scheduling quality factors are vital to improving end-user satisfaction, so this study focused on correlated discriminative quality factors for optimal resource scheduling in cloud networks.

Resource management (RM) is signified as a protection activity containing diverse workloads and resources from the submission to the workload's execution. The RM in the cloud contains 2 phases: a) resource scheduling (RS) and b) resource provisioning (RP). The RP is determined to detect sufficient resources for the specified workload based on QoS pre-requisites described by the cloud's consumers. At the same time, RS is mapping and performing cloud consumers' workloads based on RP's chosen resources.

Based on QoS pre-requisites, resource scheduling for sufficient workloads could be a challenging task. For effective resource scheduling, it is required to deliberate the requirements of QoS [1]. Hence, there is a requirement for uncovering RS's research tasks to perform the workloads deprived of impacting other QoS pre-requisites.

RS is an evolving research domain in the cloud because of the huge resource cost and execution time. Diverse RS factors and criteria are directed towards divergent classifications of RSAs (Resource Scheduling Algorithms). The effective RS lessens the cost of execution, energy consumption, performance time, and deliberating other QoS essentials such as availability, reliability, scalability, and security.

This paper is structured as follows. Section 2 discusses the various existing solutions that are closer to optimal cloud resource scheduling and its quality factors, while Section 3 presents correlating discriminative quality Factors for Optimal Resource Scheduling. Section 4 presents the experimental setup and empirical setup. The conclusion of Section 5 includes the future scope of the work.

II. RELATED WORK

The researchers have contributed "Multi-objective optimization scheduling" based on considerations such as economic costs, system execution, confines, and consumption of energy. By deliberating computational resources, the scheduling model is suggested, which segregates the budget costs and resources for lessening the task length, hence reducing the completion time of the task and enhancing the resource utilization of the system [2]. The work [3] presents fast completion time replication algorithms for "task-based replication." Initially, the algorithm adapts fuzzy clustering for preliminary resource pre-processing and later implements task duplication and acyclic graph scheduling. By deliberating the execution times of task, utilization rate, and resource costs are considered in the cloud environment utilizing multi-output, multi-input feedback "control dynamic resource scheduling algorithm" for assuring application under time confines for the optimal implementation execution [4]. For indefinite parameters in a hybrid environment, two "dynamic resource allocation" algorithms utilizing the Pareto optimization model have been suggested based on deadline and cost restraints [5].

Nevertheless, two of the algorithms' time intricacies are maximum, and both are higher than or equivalent to O (n2). The "adaptive workflow scheduling heuristic" model, which considers the confines of time and cost, has been proposed, even though the method schedules only data workflow analysis in the hybrid environment of the cloud [6]. The work [7] presents that the “Multi-objective scheduling” model is proposed based on cost & time optimization objectives with storage & bandwidth confines.

The model concentrated on enhancing the usage of “private cloud resources” for attaining the balance between costs and performance. The work [8], [9], [10] presents the scheduling issue in the way the same to concentrate on current research. For addressing the optimization and IaaS provider benefits, here, an “adaptive hybrid cloud particle swarm optimization scheduling algorithm” has been proposed. Nevertheless, this model only deliberated the cloud provider’s benefits without any cost from the users’ perception. The work [9] presents further; the researchers have suggested that the concentration needs to enhance the overall system’s performance despite whether exploring private or public resources of the cloud.

Lastly, the task outsourcing towards the public cloud method is suggested for lessening the outsourcing cost while simultaneously increasing the rate of using the internal cloud data center [10]. Consequently, the research assumed mathematical programming for optimized scheduling. Nevertheless, this method cannot solve scheduling issues containing a huge amount of data, and its “optimization objectives” are costly. The work [11] presents the cloud RM program’s proposal based on identical objectives of increasing the utilization of resources and lessening the costs. Nonetheless, the method is mostly utilized for migrating on and off the virtual machine and is not implemented for the real instance of optimizing the task scheduling.

Researchers in [12] analyzed different job types along with the availability of resources and developed a scheduling strategy that performs at a resource broker. However, the model was deported due to its computational cost and scheduling overhead. The contemporary contribution [13] portrayed a resource scheduling strategy for IAAS, using multiple Quality factors to schedule the resources. However, the contribution estimating optimality of resources has been limited to quality factors such as make-span, price, and availability. The quality factors linked to the context of the target IAAS are not in the scope of this contemporary model, and load is the other crucial factor, which is not in the scope of this contemporary scheduling strategy. Jiang et al. [15] investigated the scheduling of concurrent workflows in high-performance computing resources (HPC clouds). They describe a scheduling strategy that tries to reduce the total cost of computation, communication, and the earliest possible start time. In the last decade, a dynamic algorithm [16] for load balancing had been proposed. The static algorithm requires extensive knowledge of the forthcoming quantity of requests (tasks) and the availability of cloud-based virtual machines (cloud resources). When the number of clients grows, a long auction deadline interval will have a detrimental effect on the cloud service provider's earnings. Proposed a Cloud Resource Broker (CRB) by Somasundaram et al. [17] that has been assisted by an adaptive load balancing (ALB) and elastic resource provisioning and de-provisioning and (ERPD) mechanism. Yang et al. [18] proposed the bat algorithm (BA) as a unique heuristic optimization method in 2010, and a number of enhanced variants have been developed to deal with cloud computing resource scheduling. In [19], used stochastic integer programming to solve problems involving resource provision optimization. In a cloud computing context, the technique reduces the total cost of resource provisioning. The optimal solution is derived using a two-stage approach for formulating and solving stochastic integer programming. [20] In this research, the BAT method is utilized to address the multi-objective workflow scheduling problem in the Cloud, with the goal of optimizing execution time and reliability. Comparative simulations using the Basic Randomized Evolutionary Approach (BREA) were conducted, and it was observed that the BAT algorithm outperforms the other algorithm. In [21], an Opposition Learning-based Grey World Optimizer Algorithm is presented as a hybrid strategy for reducing the duration and expense of Cloud jobs. The evolutionary algorithm for cloud-based e-learning workload scheduling was introduced to optimize the scheduling of e-learning workloads subject to a predetermined set of conditions [22]. The two-tier VM architecture includes a front and background VM that dynamically share the VM's processing speed [23]. The issues of load balancing include scalability, availability, and load migration. To solve these obstacles, the hotspot mitigation algorithm [24] was created. [25] offered a detailed comparison of resource scheduling methods and resource allocation policies. This survey focused on resource scheduling and left other aspects of distributed computing out. It is based on the Imperfect Information StackelBerg Game (IISG) with a hidden markov model [26]. (HMM). Due to the cloud's heterogeneous and dynamic character, it's vital to deploy models that benefit both parties. It includes execution time, communication delay, reaction time, migration time, etc. Scheduling reduces completion time [27] and maximizes resource usage [28, 29]. Cloud scheduling is difficult due to the uncertainty of arriving jobs [30]. A Profit Maximization Algorithm (PMA) can address the profit maximization problem by dynamically arranging all arriving workloads in private or public clouds [31].

With these common constraints observed in these contemporary models, this manuscript aimed to derive a novel resource scheduling strategy intended to estimate the degree of optimality of the corresponding resource through contextual quality factors defined.

III. Correlating Discriminative Quality Factors (CDQF) for Optimal Resource Scheduling

This manuscript’s contribution portrayed a novel method that schedules the resources in IAAS of cloud computing under a heuristic measure called the degree of resource optimality (dro) that has been estimated by using diversified quality of service factors related to the context of the service called IAAS. The adopted qualities of service factors related to the resources of the IAAS are (i) Degree of Response Time (ii) Degree of Service Denial, (iii) Degree of Realization, (iv) Degree of Load Adoption, and (v) Degree of Cost Feasibility.

The information about the task(s) initiated at the SAAS includes the roundtrip time that indicates the arrival and expiration time of the corresponding task, the required service, and the resource’s acceptable budget. Based on the corresponding task(s) information header, the resource broker performs the resource scheduling under the proposed scheduling strategy.

A. QoS Factors of the Resources

The proposed method of resource scheduling in IAAS of cloud computing estimates the optimum scope of pairing the task(s) initiated at SAAS and the available resources at IAAS under the diversified quality of service factors. Unlike the traditional scheduling strategies, the proposal derived quality of service factors in the context of Infrastructure-As-A-Service (IAAS), which are used further to estimate the optimality of a resource to be scheduled.

Primarily, the above-stated approach has evaluated the projected quality metrics of resource transmission for overall resources available. Later, these resources are ordered as per quality metrics, and these are deliberated to be the prominent pre-requisite for optimal utilization of the resource. Moreover, this model has been utilized to evaluate every optimal metric of resource utilization, which has been exhibited regarding the available resources and has been discussed in the below sections.

By receiving the task's headers, the scheduler has scheduled the corresponding tasks towards optimum resources, which attain the task. Moreover, this article's intent is optimal resource scheduling for attaining high optimality towards completing tasks and utilizing resources. Here, the resources set, which were available towards schedule were $R = \{r_1, r_2, r_3, ...r_x\}$.

Resource scheduling towards tasks has been required as the utilization of resources and completion of the task. Moreover, the resource selection by the degree of resource optimality is scheduled for the respective task proposed in the manuscript. Here, aspects for optimal utilization of resources have been explored as follows:

- Often, the resource reflects the divergent scope and diversified QoS factors.
- The primary concern of metrics associated with the quality of resource utilization is divergent from one another.

Thus, it is evident that resource, which has scored better under QoS is not optimal, often under manifold objective quality parameters. Further, in terms of this limitation, this contribution's projection deliberates manifold objective quality parameters for scheduling resources for a respective task.

The depicted diversified quality factors of the resources recommended towards resource scheduling in IAAS are,

1) Degree of response time (drt)*:* This metric term the maximum time required for the corresponding resource to respond to the resource broker, which is the aggregate of mean value and mean deviation observed from the past anomalies of the response time of the corresponding resource observed by the resource broker. This metric was critical during resource allocation (s) to the deadline constrained task(s) (Eq. 1).

$$art(r) = \frac{1}{n}\sum_{i=1}^{n} rt(t_i, r)$$

$$mdrt(r) = \frac{1}{n}\left(\sum_{i=1}^{n}\sqrt{\left(art(r) - rt(t_i, r)\right)^2}\right) \tag{1}$$

$$drt(r) = art(r) + mdrt(r)$$

2) Degree of service denial (dsd)*:* The Degree of service denial is another crucial factor of quality of service that indicates the scope of unresponsiveness of the scheduled resource, which is the aggregate of mean and mean deviation of unresponsive schedules against the total number of schedules of the corresponding resource (Eq. 2):

$$rsr(r_i) = \frac{\sum_{j=1}^{ruc(r_i)}\begin{Bmatrix} 1 \exists reschedule\ is\ true \\ 0 \end{Bmatrix}}{ruc(r_i)} \tag{2}$$

From the above-stated equation, the notation $rsr(r_i)$ signifies the resource r_i rescheduling rate representing the schedules ratio perceived in averse to the number of times the r_i has been scheduled. Furthermore, the representation $ruc(r_i)$ indicates the actual amount of times r_i has been scheduled.

3) Degree of realization (dr)*:* The other quality factor of resource scheduling adopted is Degree of Realization, which is the absolute difference between the mean count of successful task realizations and the corresponding mean deviations.

$$\boldsymbol{ar(r) = \frac{1}{n}\left(\sum_{i=1}^{n} 1\exists task\ t_i\ realized\right)}$$ // average of realization.

$$mdr(r) = \frac{1}{n}\left(\sum_{i=1}^{n}\left(ar - \begin{Bmatrix} 1\exists if\ task\ t_i\ realized \\ 0 \end{Bmatrix}\right)\right)$$ // mean distance of the realization.

$dr = r - mdr$ // degree of realization.

4) Degree of load adoption (dla)*:* The expected load on the resource during the stipulated schedule expected by the task(s) is another quality factor of the resources labeled as Degree of Load Adoption. The estimation of load adaption carried as follows:

Find the time interval of the resource in use, which is the average time of the corresponding resource against the total number of times that resource is scheduled.

Find the number of time intervals of the resource, which is the ratio of the total time that resource in service and the time interval.

Then find the mean load and mean deviation of the load observed in all of these time intervals. The aggregate of these mean load and mean deviation of the load can denote the Degree of Load Adoption.

$$tin(r) = \frac{1}{n}\sum_{i=1}^{n} et(t_i, r)$$ // time interval

$$al(r) = \frac{1}{n}\sum_{i=1}^{n} l(tin_i, r)$$ // mean load

$$mdl(r) = \frac{1}{n}\left(\sum_{i=1}^{n}\sqrt{\left(al(r) - l(tin_i, r)\right)^2}\right)$$ // mean load deviation

$$dla = al(r) + mdl(r)$$ //degree of load adoption

5) Degree of cost viability (dcv) *:* The resource cost is crucial; resource scheduling is carried under the Service Level Agreement. The client who initiated the task accepts the pay per resource, which is certainly lesser than the upper limit concluded in SLA. Hence, the resource with minimal cost would be most viable. However, it is not at the loss of other quality factors. In this context, rather than opting for a resource with minimal cost, the proposed scheduling strategy adopts a resource that is qualified under other quality factors and has a cost of pay per use as lesser than the agreed budget level. The selected resource's coast viability can derive as the difference between the max level of the agreed cost and the estimated cost of the resource against pay for one use (Eq. 3):

$$ac = \frac{\sum_{i=1}^{n}\left(ecr(r_i) - mac(t)\right)}{n}$$

$$mdc = \frac{\sum_{i=1}^{n}\left(\sqrt{\left(ac - \left(ecr(r_i) - mac(t)\right)\right)^2}\right)}{n} \quad (3)$$

$$dcv = ac - mdc$$

B. The Heuristic Measure (Degree of Resource Optimality (dro) *)*

Let Degree of Response Time (drt), Degree of Service Denial (dsd), Degree of Realization (dr), Degree of Load Adoption (dla), and Degree of Cost Viability (dcv) as a set of QoS metrics denoted for each resource r_i as $M_{(r_i)} = \{drt, dsd, dr, dla, dcv\}$.

To explore the proposed model, let $dcv(r_i), dla(r_i)$ be QoS factors that have been utilized for identifying every resource scope. These key metrics have been utilized for sequencing the resources, as described in the following algorithm.

The initial process normalizes the feasibility of cost and degree of load adoption (dla) as follows and as shown in Fig. 1:

step 1. $foreach\{r_i \exists r_i \in R \wedge i = 1, 2, 3, ..., |R|\}$ // Begin.

step 2. $ndcv(r_i) = dcv(r_i)^{-1}$ //degree of cost viability in normal form $ndcv$, which lies among 0 & 1.

step 3. $ndcv_{abs} \leftarrow abs(ndcv(r_i))$ //The set $ndcv_{abs}$ comprises absolute values of the corresponding degree of cost viability in normal form perceived for every resource.

step 4. End // of step 1.

step 5. $foreach\{r_i \exists r_i \in R \wedge i = 1, 2, 3, ..., |R|\}$ // Begin.

step 6. $ndla(r_i) = dla(r_i)^{-1}$ // the degree of load adoption in a normal form $ndla$ which is in the range of 0 to 1.

step 7. $diff_{abs} \leftarrow abs(ndla(r_i))$ //The set $diff_{abs}$ comprises absolute values of entries in $diff$.

step 8. End // of step 5.

step 9. $foreach\{r_i \exists r_i \in R \wedge i = 1, 2, 3, ..., |R|\}$ // Begin.

step 10. $km(r_i) = 1 - \left(ndcv(r_i) \times ndla(r_i)\right) \exists \left(ndcv(r_i) < 1 \| ndla(r_i) < 1\right)$ //the outcomes have been subtracted from one that is to attain maximum value since the product of 2 decimal fractions provides another decimal fraction, which is lower than fractions of decimal incorporated in multiplication.

step 11. End // of step 9.

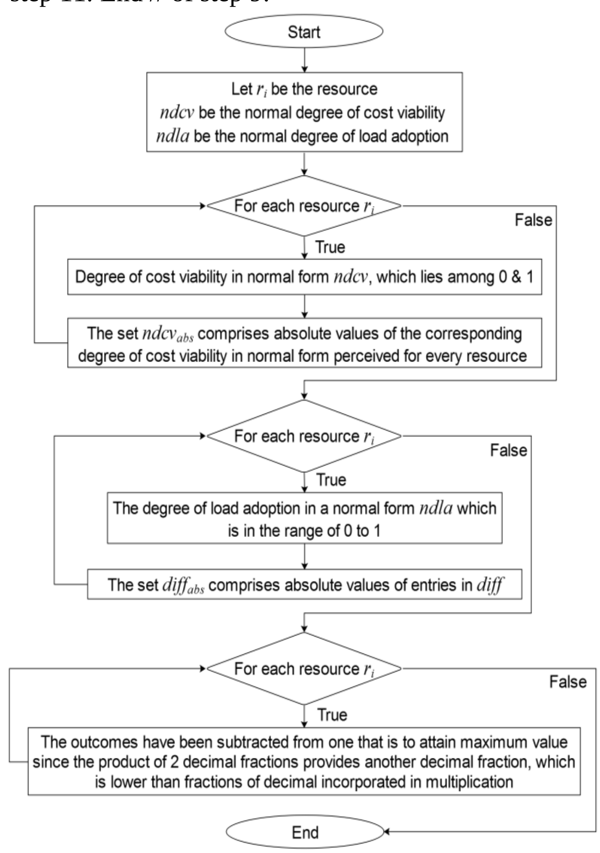

Fig. 1. Flowchart Representation of the Heuristic Measure.

Later, the resources available have been rated about every metric so that every resource would have a unique rating for a metric. Moreover, resources would be rated in an increasing sequence of resulting metric values. When maximum values are optimal, then such a resource possessing minimum value over the resulting metric would be rated as one. Besides, resources possessing maximum value for the respective metric would be rated in the form of $\{n \exists n \le x\}$. The representation x depicts the number of resources. When minimum values are said to be optimal, then resources would be rated in a decreasing sequence of resultant metric values so that the resource possessing maximum value for the resulting metric has been rated as one. In contrast, the resource possessing minimum value for the resulting metric has been rated to be $\{n \exists n \le x\}$.

With the process completion, every resource reflects manifold ratings about specific quality parameters. Moreover, these ratings would be utilized as input for assessing the Degree of Resource Optimality $dro(r_i)$ as follows (Eq. 4):

For each resource $\{r_i \exists i = 1, 2, ..., x\}$ // Begin.

$$\mu(r_i) = \frac{km(r_i) + drt(r_i) + dsd(r_i) + dr(r_i)}{4} \tag{4}$$

//The above-stated equation portrays average ratings attained for divergent resource r_i metrics.

$$dro(r_i) = \left[\frac{\left\{ \sqrt{(\mu(r_i) - km(r_i))^2} + \sqrt{(\mu(r_i) - drt(r_i))^2} + \sqrt{(\mu(r_i) - dsd(r_i))^2} + \sqrt{(\mu(r_i) - dr(r_i))^2} \right\}}{4} \right]^{-1} \tag{5}$$

Eq 5 Degree of Resource Optimality $dro(r_i)$ is the inverse of root mean square distance of ratings allocated to a resource r_i as the lowest distance is said to be optimum.

With the completion of evaluating the degree of resource optimality for specified resources, then resources would be organized in decreasing sequence of their rating attained for prominent metrics.

Further, choose a set of resources possessing an optimal rating about key metrics under the given threshold.

The chosen resources have been organized in decreasing the sequence of their Degree of Resource Optimality $dro(r_i)$ that assists in projecting the optimal resource in the primary place of its sequenced list. Here, a similar order would be considered the preferred order to select resources regarding the task schedule.

IV. Experimental Setup and Empirical Analysis

The empirical study compares of projected CDQF model and other existing "job scheduling with efficient resource monitoring (JS-ERM) approach [12]" & "multi-objective scheduling method based on ant colony optimization (MOSACO) [13]" that is simulated utilizing Cloudsim [14]. Here it allows for simulating high dimensional CC network synthesizing input jobs so that there could be no priority sequence applicable to corresponding jobs. The confines are executed for performing simulation from 1 processor towards another, and pre-emption is not enabled. They are scheduling the resources utilizing the QoS factors considered by proposed & other existing methods to analyze the performance. Moreover, we noticed the metrics of performance discussed in the next segment at distinct intervals of time.

The proposed CDQF has been assessed by comparing it with another JS-ERM [12] and MOSACO [13] contemporary approaches. Here, performance would be measured under several QoS metrics such as completion rate of the task, resource utilization rate, and rescheduling rate.

The rate of resource utilization perceived for CDQF would be high and maximum when compared with other contemporary MOSACO and JS-ERM approaches. Here, the rescheduling rate perceived for the CDQF model would be linear and minimal compared to other approaches. The rate of resource scheduling has been perceived as low in CDQF, which delivers an optimal job completion rate. Here, process complexity would be minimal for CDQF, which is minimum because of the scalable method modified for the degree of resource optimization assessment.

Here, Table I and Fig. 2 depict the rescheduling rate noticed at diverse intervals of time. The perceived rate of rescheduling is averse to the load of the task. This figure signifies that the projected model of this contribution CDQF has been prominently the best for lessening the rescheduling rate compared to other approaches. Further, Table II and Fig. 3 portrays that the rate of job completion perceived for the proposed model CDQF would be recommendable and prominent compared to MOSACO and JS-ERM contemporary approaches. Table III and Fig. 4 portray that CDQF added an advantage over the other two existing models for resource utilization rate that is considered a significant objective of resource scheduling techniques.

TABLE I. Resource Rescheduling Rate Statistics

JS-ERM	0.05	0.052	0.07	0.09	0.12	0.135	0.14
MOSACO	0.04	0.06	0.065	0.08	0.095	0.1	0.12
CDQF	0.02	0.025	0.03	0.035	0.04	0.07	0.085

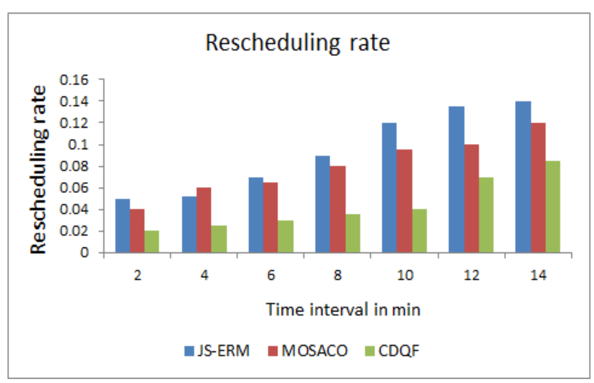

Fig. 2. Resource Rescheduling Rate Perceived.

TABLE II. JOB COMPLETION RATE STATISTICS

JS-ERM	0.96	0.92	0.92	0.91	0.9	0.895	0.89
MOSACO	0.965	0.94	0.93	0.93	0.925	0.922	0.922
CDQF	0.975	0.97	0.97	0.965	0.95	0.95	0.95

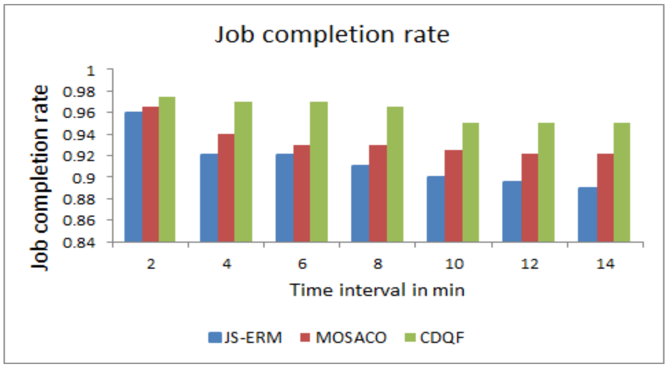

Fig. 3. Job Completion Rate Perceived.

TABLE III. RESOURCE UTILIZATION RATE STATISTICS

JS-ERM	0.59	0.6	0.7	0.72	0.8	0.82	0.89
MOSACO	0.8	0.82	0.88	0.9	0.9	0.87	0.92
CDQF	0.88	0.9	0.91	0.91	0.93	0.93	0.94

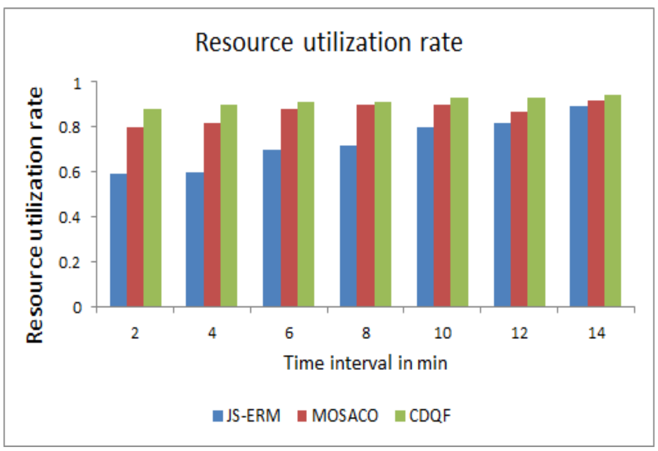

Fig. 4. Resource Utilization Rate Observed.

V. CONCLUSION

In this manuscript, a quality-aware scheduling algorithm optimizes the completion of tasks and resources scheduling cloud computing. Moreover, this article projected a novel scale known as Degree of Resource Optimality that signifies resources fitness under diversified QoS proposed metrics. The outcomes attained from this contribution's projected model have been compared to the other two existing methods, JS-ERM & MOSACO. The performance analysis is exhibiting that the projected method has been surpassed compared with the other two existing methods for divergent quality metrics. Here, empirical analysis of the proposed method of this contribution might impact further research for development. The load balancing and scheduling technique for attaining optimum VM scheduling (virtual machines) as resources in CC.

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Development of Novel Algorithm for Data Hiding on Mobile Application

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***Abstract*—We can easily observe that in the current era of communication, Computers, mobile phones, and the Internet are widely used mediums. In such an environment, information security is an important issue. The most common techniques used for information security are Cryptography and Steganography. Many research works have been done on image Steganography. These images have different kinds of formats like BMP, GIF, and PNG. Several compression methods are available which applied to the images having the format BMP, GIF, and PNG is comparatively less effective than the JPEG image. JPEG compression steganography method is complex to implement even then some algorithms have been developed for it. They provide single-level or two-level information securities. This paper presents a method in which is the combination of Cryptography and Steganography is used over android mobile phones. Here we are performing encryption two times on data to be hidden and then that encrypted data hidden both in text and image. We are using the Advanced Encryption Standard (AES) algorithm to hide text within a text, Discrete Cosine transform (DCT) for image steganography, and Data Encryption Standard (DES) for encryption of text. This paper gives the idea of three-level information security over the android environment.**

Keywords—Steganography encryption; discrete cosine transform; DES; F5Algorithm

I. Introduction

Information security is a popular research area. It attracted researchers towards the security concept of data by using different kinds of techniques. The commonly used are Steganography, watermarking, and cryptography. When we look at all these techniques, we found that Steganography gives more security comparatively other methods. As well as digital communication technology has changed security features also required some variations. Information security attracted many researchers and has become the widely scoped area of research in wireless and mobile communication. The field of Steganography is very vast, but researchers have been motivated toward mobile steganography because of the intensive use of mobile phones as well as the exchange of information among the users. In the same context, "Short Messaging System (SMS) was introduced with GSM mobile phones and became too much popular among users" [2]. After some time, the multimedia message was introduced and gained more popularity due to its advanced features. Later, smartphones have come to light with many advanced features for communication. It is a small handy portable device that the user can carry with him anywhere. Thus, users can use these devices in various ways like photo capturing, sharing of information in images, audios videos and calling, etc. To stop unauthorized access and attacks, we must have to use systems with some data security techniques. We have described few data security techniques earlier in which one of the trendiest techniques is steganography.

II. Steganography

We start with the security of information that so many techniques are present. Fig. 1 depicts the different disciplines of information hiding. Steganography alludes to the study of "imperceptible" correspondence. In contrast to cryptography, where the objective is to make safe correspondences from a user, steganographic strategies endeavor to hide the very nearness of the message itself from an onlooker [4]. Steganography is the craftsmanship and study of imparting so that the nearness of a message can't be distinguished [5].

Steganography is the science that includes imparting mystery information in a suitable sight and sound bearer, e.g., Image, sound, and video. It goes under the presumption that if the element is noticeable, the purpose of assault is obvious, therefore the objective here is consistently to disguise the very presence of the installed information [9]. The word steganography is of Greek cause and signifies disguised composition from the Greek words steganos (στεγανός) signifying secured or ensured, and graphei (γράφη) signifying composing. The principal recorded utilization of the term was in 1499 by Johannes Trithemius in his Steganographia, a treatise on cryptography and steganography masked as a book on enchantment. By and large, messages will give off an impression of being something different: pictures, articles, shopping records, or some other spread content, and, traditionally, the concealed message might be in undetectable ink between the obvious lines of a private letter [14]. Steganography implies concealing the presence of data in such a way along these lines that nobody can recognize. Three procedures of data security are fundamentally the same Cryptography, watermarking, and steganography. Pictures are used as the bearer to perform steganography. A mystery message is implanted in the transporter picture so that nobody can recognize that mystery message. Ancient steganography worries about the ways of inserting the mystery message in a spread picture. The implanting needs key without which an outsider cannot identify or evacuated the original message. The cover picture with the implanted message is called Stego Image.

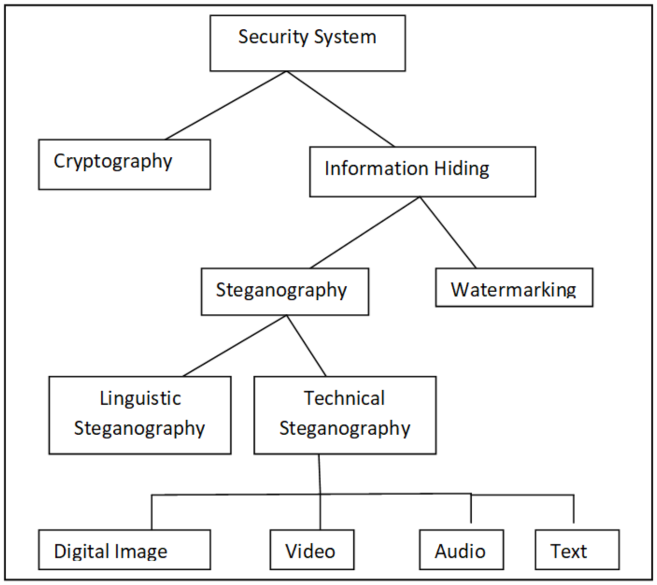

Fig. 1. Types of Security System.

A. *Working of Steganography*

A steganography algorithm shows a combination of a mystery message-which needs to cover up, picture – which contains the implanted message. The general working of steganography is to get the message to stow away, get the picture wherein information to cover up, Apply the suitable algorithm which produces the stego picture. This Stego picture sends to the beneficiary, receiver interprets the stego picture and gets the first message.

With the help of Fig. 2 general idea of steganography can be understood.

The message is the information that the correspondent needs to keep secret. It may be a plain content, figure text, another picture, or something that can be implanted in a bitstream, for example, a patent mark, an incognito correspondence, or a sequential digit. Key is a particular word, which guarantees that the beneficiary who realizes the relating disentangling key will have the option to remove the message from a Stego picture. The spread picture is likewise called a transporter. The generated picture with the secretly inserted message is known as the stego message. Recouping data from a Stego image requires the stego picture itself and a relating deciphering input if the input is used throughout the encoding procedure.

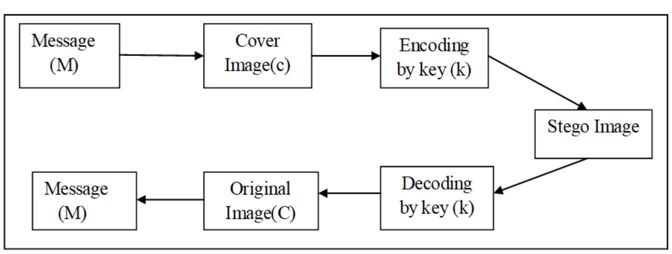

Fig. 2. Representation of Steganography.

III. Cryptography

Cryptography is the preparation and examination of disguising information. It consolidates the request for number juggling, programming building, and electrical structuring. Cryptography is encryption, which is the route toward changing over standard information into muddle information. Deciphering is the opposite system of getting authentic information from confounded information.

A. *Working of Cryptography*

A cryptographic estimation works in blend in with a keyword, number, or articulation—to encode the plain text. The proportional plain text scrambles to different text with different keys. The security of encoded data depends on two things: the nature of the cryptographic estimation and the secret key. A cryptographic algorithm, in addition to every potential key and all the conventions that make it work, involves a cryptosystem. With the help of Fig. 3, the general idea can be comprehended.

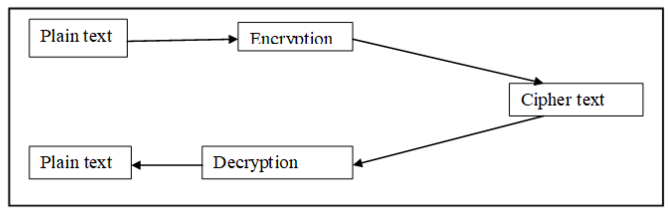

Fig. 3. Cryptography Concept.

IV. Literature Review

Most of the work has been done in the field of steganography. Mainly steganography has been done on bit map pictures, gif pictures, and grayscale pictures.

The most widely recognized and easiest steganographic technique is the least significant bit inclusion strategy is presented earlier. The least Significant Bit Substitution strategies are called due to how the message information m is inserted inside a spread picture c. In software engineering, the word Least Significant Bit (LSB) alludes toward the littlest (right-most) piece of a parallel succession. The organization of binary is with the end goal that every number may just be either a 0 or a 1, frequently idea of as on separately. Beginning from the right, the worth (if on) signifies a 1. The incentive to one side (if on) means a 2, etc. wherever the qualities are twofold every time [1]. Afterward new encoding strategy utilizes a matrix. The best appropriate procedure for jpeg steganography is considered F5 algorithm [2]. The first recorded use of steganography found from 440 BC back when Herodotus informed to Greece about the forthcoming attack by writing a message on the wooden and covered it by wax. Another example of ancient steganography is Histiaeus who shaved the head of his slave and tattooed the message on it after hair grown message was hidden [3]. In this author has provided the review of steganography techniques and steganalysis technique [4]. According to this paper, a secure stego system is proposed using the stego text distribution close to the cover text distribution. Here observer no need to know about the secret key. The embedding function depends on the cover text distribution [5]. This paper presented and discussed the possibility for using steganography in MMS and also suggested SMILE Steganography. Here presented algorithms and evaluation are on theoretical basis only [6].

As well as mobile phones became popular, so MMS techniques were used for communication. So, there was also some research in such area which shows the calculation for hiding information in MMS utilizing Portable Network Graphic picture also shows the novel strategy for steganography utilizing both content and pictures [7]. Steganography technique used in a game known as the Sudoku puzzle. It shows that how we can hide data in the Sudoku puzzle for secure information transfer [8]. In this paper different analysis of existing steganography has been done. Here are also given some differences between steganography and watermarking. Some questions may also arise such that is this technique is useful or not? [9]. Here we find how we can use steganography in MMS for Smartphones. Two-level of security has provided using image and text both [10]. Here author suggested Elliptic Curve Cryptography method for MMS security purpose [11]. This paper gives a comparative study of different mobile environments and their development technology. Also, introduce security issues for android OS [12]. In this paper authors provided steganography for JPEG image over the mobile phone. Here algorithm is implemented through the combination of text, image, and encryption [13]. This paper gives idea of hiding the text message inside one small image using LSB and then hided that image in larger image using DWT algorithm. It is implemented on gray images not on color images [14]. In this paper author implemented steganography method on android environment using LSB method and also used TEA algorithm for cryptography also for reducing the size of message LZW compression method is used [15]. Multi-Level steganography with dissemination in painting and YASS Algorithm on the external level and One-Time stuffing of the mystery note with key picture and YASS on internal level used for steganography [16]. In another paper author described about a model called Ste-Chy as an evidence of idea of the blend of the strategies. This methodology helps the client as far as the trading of secret information by online offer in Android base media. In support of the classified confirmation reason, the secret message is concealed along with the objective picture. At an adequate level image is created by this work using nature of original and stego pictures [17]. In [18] authors were used emoticons or lingoes to hide the information. He has proposed his idea for embedding data in emoticons or using lingoes in SMS than the recipient can extract the hidden information. In [19] we find the information regarding different steganographic techniques and gives performance metrics for mobile image steganography. In [20], creators have built up an android application through which we can shroud information behind the picture, and we can share an apk document through WhatsApp. This application is created by utilizing steganography and the LZMA firmness strategy. In this research authors have given idea of video watermarking using steganography. For steganography they have used DCT method. Here water mark is embedded inside the quantized coefficients [21]. It gives improvement in multiphase encryption by encrypt the data with different encryption algorithms. Here proposed algorithm itself append the information along with secret text on the other hand in multiphase sender provide the specific order to receiver for decrypting the message [22]. In this work creators suggested Image steganography using k means clustering and AES encryption together. Messages are hided in object area which form as cluster with that encryption has also used for improvement [23]. Benefit of this application is it gives twofold security by utilizing hiding and firmness strategy. For jpeg image, a steganography technique is proposed. A part of data may be lost after the quantization of frequency values in the JPEG compression procedure, in the proposed method, the embedded message is added to the image after the discretization stage. The method utilizes two adjacent pixels in the steganography process [24]. The authors suggested cryptography and Steganography method for smart phones. Here they have used RSA algorithm for encryption and LSB insertion method for information hiding [25]. Message is sliced in parts and hided in multiple images. LSB technique is used for each image and image contain some header information so that at the receiver side any specific order is not required [26]. This paper gives idea of different techniques for jpeg steganography. It summarizes various algorithms and techniques used in the past and in present. This paper also analysis's these algorithms based on the basic parameters of image steganography: Unidentifiable, robustness and hiding capacity [27]. Here author proposes a JPEG steganography algorithm to provide strength to the Stego image using DCT coefficient and maintain an even coefficient distribution based on the JPEG characteristic [28]. In this paper author has suggested LSB embedding method using BMP and PNG images. He has hided secret message in pixel values and modified values have shown in new generated images [29]. "This paper introduced the concept of steganography using bit selection of cover image. Basically, here also LSB Technique is used for hiding the secret message. Message can be in any format text or image. Here gray scale image has been taken as example to perform this operation. Secret message image must be smaller then cover image [30].This paper suggested the modification in F5 algorithm of data hiding. It is based on idea of modified matrix embedding (MME). In proposed method all nonzero AC coefficients collected in single array and divides array into small coefficient blocks, then find the coefficient with least distortion to embed message [31].

The rise of mobile phones has led to new demands of android operating systems and applications to run on it. Nowadays image steganography is a very wide area for research work. The field steganography is very vast but, in that field, and the present requirement mobile steganography work motivates the researchers to introduce some new and innovative ideas. Steganography poses a lot of interesting research problems and there are so many techniques to implement it and require some further improvement. There is still not too much work that has been done on JPEG steganography over cell phones.

V. Motivation

There is too much research that has been done on image security over the different kinds of image formats BMP, GIF, and PNG. Several compression methods are available that applied to the image having the formats BMP, GIF, and PNG is comparatively less effective than the JPEG image. Even the

JPEG compression steganography method becomes difficult though some algorithms show JPEG Steganography. But they provide a single-level or two-level security. Most of the techniques are computer system based but not for mobile phones. Now day's everyone has a mobile phone became so handy. Chatting is one popular application of mobile through which one can share different kinds of data such as pictures, audio, and videos among users. When we consider information security over mobile phones, steganography is the best security procedure because most of the correspondence with the assistance of sharing pictures. Although steganography has been done in all types of image format still this technique is an interesting research area for mobile application. The motivation for this work is that steganography is the way to provide secure communication. Its main goal is to hide information so that no one can detect it and provide information securely to the sender. Hackers or attackers cannot identify the hidden message in any way. In this carrier, the image keeps a secret message and looks like an original image so that intruder cannot pay attention to it. Most security agencies are using this technology for secure communication. In the present scenario, the mobile phone has become a popular device for communication due to which information flows freely, so information security becomes a primary concern. Hence this motivated mobile application development.

VI. Proposed Method

Earlier work is carried out using text steganography and image steganography and for this purpose PNG (Portable Network Graphic) image was used [7].

In this work, we are using JPEG images for steganography. We will encrypt an original text message two times later split it into two halves to hide the first half in the image and the second half in the cover message.

Steps for procedure:

Input: An Image (Cover Image), Text message (Plain Text), Text message to hide

Output: Stego Image with hidden Text, One text file

1) Write Text to hide.

2) Take original image known as cover image.

3) Write Short text message which is known as plain text.

4) Encrypt the text which to be hidden using DES algorithm.

5) Re-encrypt the received encrypted data using the DES algorithm again to produce ciphertext.

6) Split the cipher text in two halves.

7) Hide the first half cipher text in Cover image using matrix encoding algorithm.

8) Hide the second half cipher text in cover message using markove chain method.

9) Generate stego image and one text file.

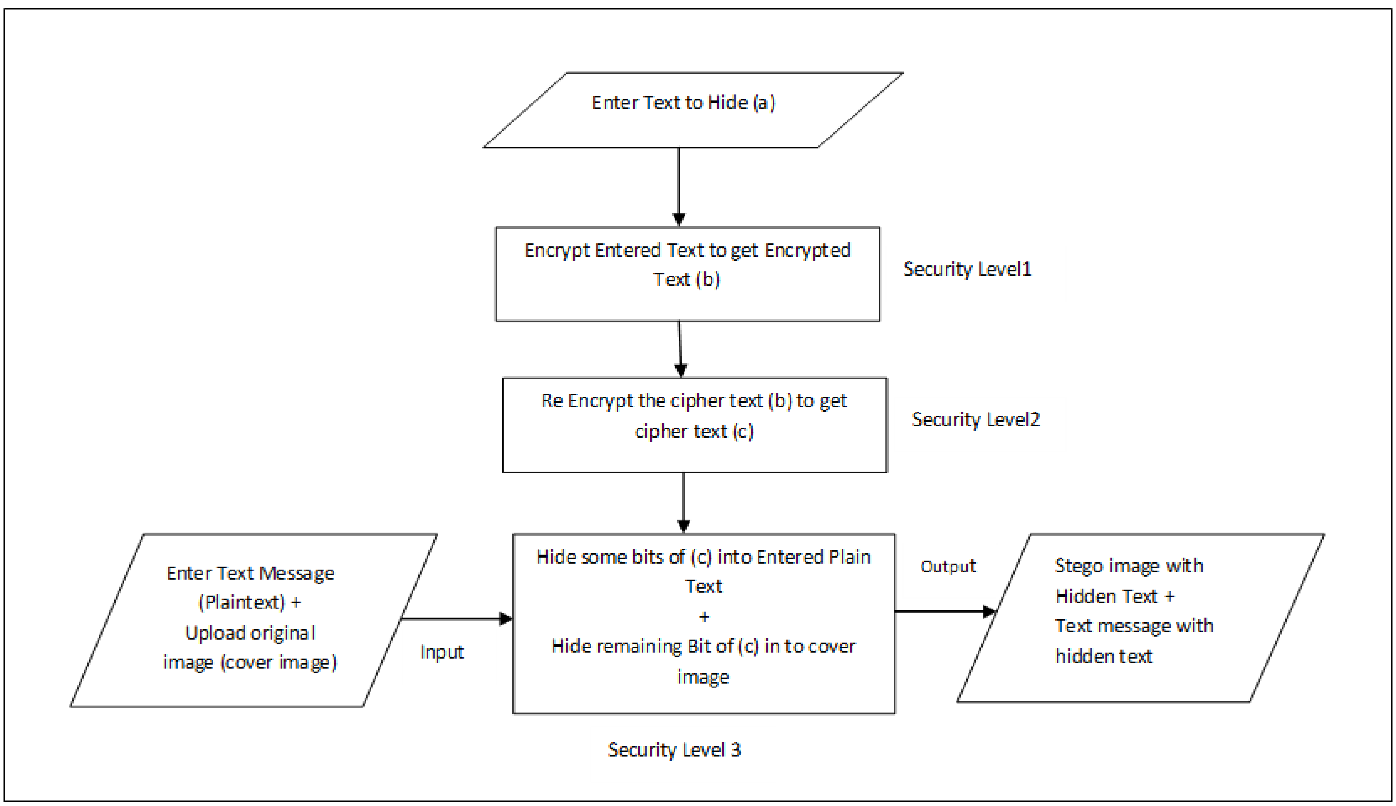

Fig. 4. Workflow Diagram.

For receiver side follow the procedure in reverse order but there we provide Stego image, Cover message and generated text file as input to extract original message Fig. 4 shows the basic idea of workflow.

Algorithm

S1: Select the image on which we have to perform operation called original image.

S2: Enter the message which must be hidden.

S3: Enter Cover Message which is used for text steganography.

S4: Apply DES Algorithm on message enter in step2 to get encrypted text.

S5: Again, apply DES algorithm on received encrypted text from previous step to get final cipher text

S6: Divide the final cipher text in two halves

S7: Take one half of cipher text and Image loaded in Step1 and Apply F5 algorithm to hide the text in image

S8: Take the other half of cipher text and Cover message (S2) apply Markov chain method to hide cipher text in cover message

VII. Implementation

To encrypt the text which has to hide, "DES Algorithm" has been used in this paper. We encrypted the text first by DES algorithm through which we received Encrypted Text and Further that encrypted text is encrypted again through the same DES Algorithm to get final ciphertext. After receiving this ciphertext, we have split the ciphertext in two half one portion to hide in the image and the other portion to hide in text. We have used the F5 algorithm to hide the text inside the image. It is most commonly used an algorithm based on matrix encoding.

We do quantization of coefficient and then we embed the message using bit position and performing XOR operation. We can understand it through an example.

We want to embed Two bits p1, p2 in three-bit places q1, q2, q3 changing one place at most.

There may be four condition arises. If we find p1 is equal to XOR operation between q1 and q3, and p2 is equal to XOR operation between q2 and q3 then we don't change in bits.

If we find p1 is not equal to the XOR operation between q1 and q3, and p2 is equal to the XOR operation between q2 and q3 then we change bit q1.If we find p1 is equal of XOR operation between q1 and q3, and p2 is not equal of XOR operation between q2 and q3 then we change in bits q2 bit.

If we find p1 is not equal of XOR operation between q1 and q3, and p2 is not equal of XOR operation between q2 and q3 then we change in bit q3. In all these conditions we do not change more than one bit.

Text hiding within text:

Hide text in text with the help of cover messages using a Markov Chain method. This generates an encryption vector based on the relationship between the cumulative character score of the cover message and each character of an input string. Decrypt messages by reversing the encryption on the encryption vector and retrieving the original message based on the cumulative character score and the relationship between the cover message and the input string.

Generating an Encryption Vector:

Take the sum of all the ascii character codes of each character in the cover message:

Example: hello,

h = 104, e = 101, l = 108, l = 108, o = 111

Sum hello = 104 + 101 + 108 + 108 + 111 = 532, this forms the cumulative character score S. Append the difference of S and the ascii character value of the input string to an Array List to form the encryption vector

S = 532

Input = "dog", d = 100, o = 111, g = 103

Evector = {532 – 100, 532 – 111, 532 - 103} = {432, 421, 429}

To hide the text encryption vector Evector, use AES – 256 Encryption Algorithm to encrypt the Array List for message. For retrieving the information at receiver side, the received Message and its Evector are first decrypted by initializing a Java Cipher object in decryption mode using the secret key yielding a decryption vector Dvector. Then it follows reverse process to get original message. Here Fig. 5 represent the GUI of developed app.

Fig. 6 Show the encoding view though which user can enter original and cover message.

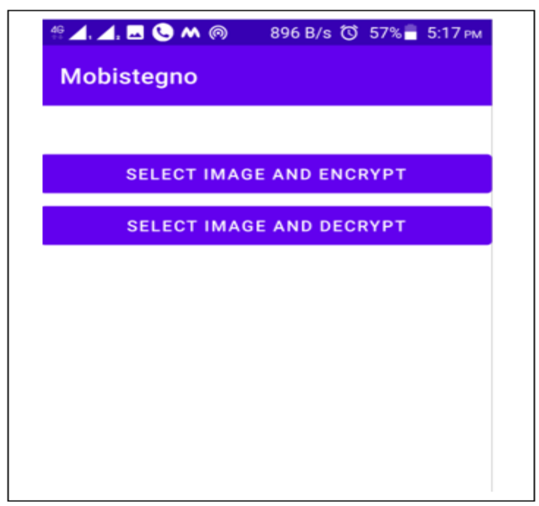

Fig. 5. App Start View.

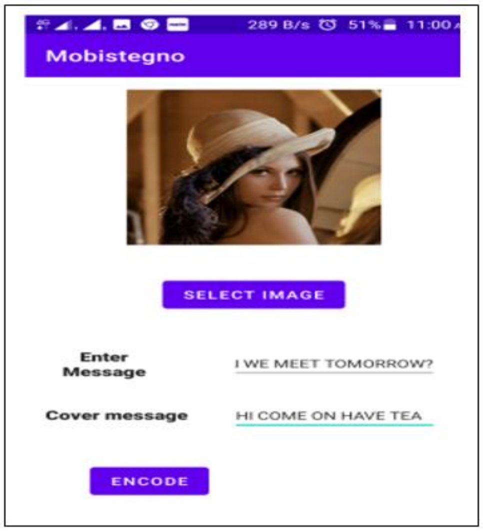

Fig. 6. Encoding View.

Fig. 7 depict the decode view of app in which user can enter the cover message to get back original message.

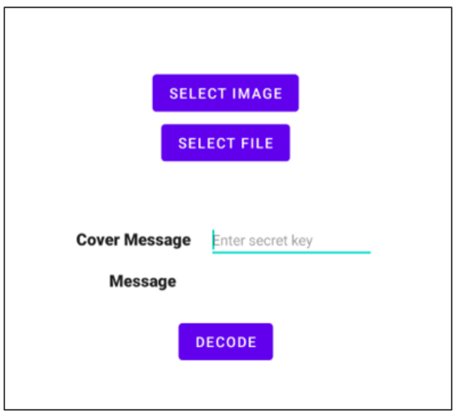

Fig. 7. Decode View.

Here the Fig. 8 represent the result view where user get original message.

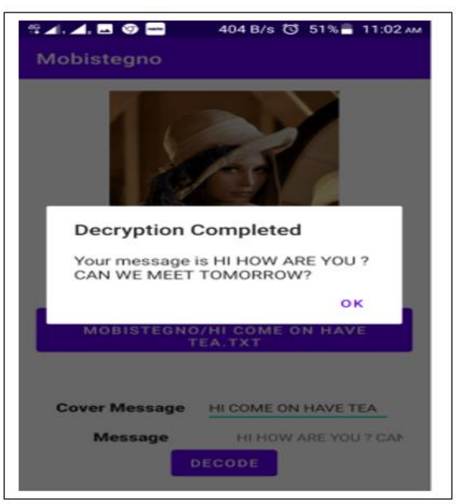

Fig. 8. Result View.

VIII. Result and Discussion

When we embed the data in the image it increases in the Mean Square Error (MSE). This automatically reduces the Peak Signal to Noise Ratio (PSNR) and vice versa. The PSNR is to be measured in decibels (dB). Usually, PSNR of more than 35db is considered good quality, so our results have good values. The lesser the MSE value higher will be the PSNR values. Equation 1 shows the formula for calculating PSNR.

$$PSNR = 10.log_{10}\left(\frac{MAX_I^2}{MSE}\right)$$

$$= 20.log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (1)$$

$$= 20.log_{10}(MAX_I) - 10.log_{10}(MSE)$$

Formula for calculating mean square error is given by equation 2.

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad (2)$$

It shows the changes between the original image and the stego image. Here m and n show height and width of the image.

We have used different images to embed the data inside. Here one message is conveyed, and text is hidden inside the image. Also, some part of the text is hidden in cover message. Here we have used three-level security for data hiding on the android environment. Table I shows the comparisons of features. Table II shows the PSNR values for different images hiding the different data. Original images contain the secret data which produces stego images. The PSNR value gives the peak signal-to-noise ratio.

Cover message for image 1: hi come on have tea.

Message to hide: hi how are you? Can we meet tomorrow?

Cover message for image2: good morning dear friend

Message to hide: dear ajay thanks for making life fun and being my friend you are most amazing person I know.

Cover message for image 3: we need urgent meeting

Message to hide: This is very important message. There is chance of terrorist attack we need army

We have implemented this on Android SDK and tested on Lenovo k6 Note also run-on Android emulator. We have calculated the PSNR and MSE values on NetBeans IDE.

TABLE I. Comparison of Algorithms

Features	**F5Algorithm**	**Previous Algorithm**	**Proposed Algorithm**
Color	Yes	Yes	Yes
Format	JPG	PNG, GIF	JPG
Security	Yes	Yes	Yes
Micro	No	Yes	Yes
Android Device	Need Modification	No	Yes

TABLE II. COMPARISON OF ALGORITHMS

Original Image	Image after Steganography	MSE Value	PSNR Value
Original Image1,JPG	Stego Image1.JPG	0.15%	46.27
Original image2.JPG	Stego Image2.JPG	0.69%	39.69
Original Image3.JPG	Stego Image3.JPG	0.39	42.18

Fig. 9. Original Image 1.

Fig. 9, Fig. 11 and Fig. 13 show the original images through which the secret message migrated.

Fig. 10. Stego Image 1.

Fig. 10, Fig. 12, and Fig. 14 represent the stego images that contains the hidden message. For retrieving an original text, these stego images are used.

Fig. 11. Original Image 2.

Fig. 12. Stego Image 2.

Fig. 13. Original Image 3.

Fig. 14. Stego Image 3.

IX. CONCLUSION

As we know that technologies have been improving in the field of communication, its result is that many microdevices have also arrived in the market. The most commonly and widely used device is the android smartphone. In such environments, the concern of security may arise that how can we keep protected our data and information. For this purpose, many researchers have used either cryptography or Steganography techniques. Some of them also tried a combination of both. When we see the previous work we found that very little work has been done over JPEG image format in the android environment and whatever the work has done they have to provide only one level or two-level security. Here we have given a method for enhancing the security by using cryptography and Steganography at three-level security over the android environment. Here hiding information in two different parts that are image and text makes it more robust to attack. We have encrypted the message two times with the DES Encryption algorithm and then divide that encrypted message into two halves so that one part is hidden in the image using the F5 algorithm and another part is hidden in the cover message using the Markov chain method for text Steganography. In this manner, two times encryption and further hiding in text and image make this system the best application to ensure data security. Till now F5 algorithm implementation is not available for android application so it is very secure application for image steganography over mobile phone. It is extensively using DES algorithm with f5, so it takes some time in processing. In comparison of other this method has advantage of security at three level which has not implemented till now on android phone using F5 algorithm for JPEG images. The limitation of this application is that it is tested on the upper than android 6 version not supported on the lower version and gives the best result for short messages, not for long payload.

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Fuzzy and Genetic Algorithm-based Decision-making Approach for Collaborative Team Formation: A Study on User Acceptance using UTAUT

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***Abstract*—Forming an optimal collaborative team is achieved using members characteristics to improve team efficiency. A team's performance may have a negative effect when a team is formed randomly. Moreover, it is quite impossible to achieve an optimal team manually as the formation can expand into countless possibilities. Hence, this paper presents a decision-making framework for collaborative team formation by incorporating Fuzzy Logic and Genetic Algorithm (Fuzzy-GA). The framework has been initiated by combining effective team formation factors such as skills, trust, leadership, and individual performance. Unified Theory of Acceptance and Use of Technology (UTAUT) is utilised to survey the readiness and technology acceptance of the organisations' employees in adopting the proposed decision-making approach to form a collaborative team. The UTAUT survey had proven that behavioural intention (BI) had a positive impact on the performance expectancy (PE), effort expectancy (EE), social influence (SI) and facilitating conditions (FC). However, behavioural intention (BI) had a negative impact on the voluntariness of use (VU); thus the transformation of collaborative team formation must be further explored to increase the team's voluntarism towards this automated collaborative team formation.**

Keywords*—Collaborative team formation; genetic algorithm; fuzzy logic; unified theory of acceptance and use of technology (UTAUT)

I. Introduction

It is important to have an effective team in an organisation, particularly where there is an issue with the operating costs. Hence, an organisation needs to enforce the team development model for developing an effective team [1,2]. A team must work together to accomplish organisational activities, share common goals and interact socially [3].

A collaborative team comprises people with a variety of skills to execute a task collaboratively, where they are able to share the resources, information, and cost to deliver optimal outcomes [4]. Positive outcomes can be reached when the team members incorporate their knowledge, work well together, and welcome feedback. It has been shown that team performance exceeded the efficiency of two self-employed people [2,5]. This indicated the importance of communication and collaboration between team members. Bahrami et al. [6] also stated that accuracy in a collaborative team is higher because the team's precision is higher than that of the individuals.

An organisation consists of employees with diverse expertise, knowledge, and experience. An efficient team can enhance the team's innovativeness. Thus, for a collaborative task to be implemented efficiently, selecting team members of a collaborative team is a crucial process. [7] stated that the problem in the collaborative team formation using the decision-making approach in selecting the team members is that they are not always strategic and do not give the best output as cost and time play a big role. Hence, numerous research was executed to ascertain the effective decision support approach to form a collaborative team in an organisation. However, not much of the research focused on studying the acceptance towards the collaborative team formation technology.

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Thus, this paper aims to study the acceptance of the proposed fuzzy and genetic algorithm-based (Fuzzy-FA) decision-making approach of collaborative team formation. To achieve this aim, the objectives of this paper are 1) to outline the combinations of factors for the decision-making system to form a collaborative team, 2) to propose a framework of a decision-making system by using Fuzzy Logic (FL) and Genetic Algorithm (GA) and 3) to evaluate the acceptance by using the Unified Theory of Acceptance and Use of Technology (UTAUT) survey.

In the next section of this paper, the related works relevant to collaborative work are presented. Subsequently, Section III highlights the framework of the collaborative team formation by finalising the team formation factors and combining the FL approach and GA (Fuzzy-GA). Section IV explains further the details of the proposed Fuzzy-GA. Section V focuses on the user acceptance survey development of the proposed Fuzzy-GA. Section VI presents the results from the UTAUT survey, which was used to evaluate the users' acceptance of the proposed framework. Section VII provides a conclusion to the paper.

II. Related Work

Leadership and trust were identified as factors for a team to have a high performance, where leadership was identified to have a direct influence on team performance, whereas trust could facilitate the leadership impacts [8]. Trust was reported to be an important factor to be considered in team formation

[9,10]. These findings showed that trust is an essential factor in establishing a collaborative team and sustaining the whole team. Zhang and Zhang [11] reported that team trust was a good predictor; thus, establishing trustworthy relationships in teams would lead to improved performance.

Skill was another crucial factor in team formation [12,13] where this factor indicated the workability of the people in the team [13]. Without the proper selection of team members with the right skills, the project to be executed might face failure and, at the same time, waste the organisational resources [12]. Fathian et al. [12] recommended three key factors: skills, collaboration network, and reliability for their proposed team formation optimisation model. These three factors were proven to support and enhance collaborative work in the context of team formation.

Knowledge was recognised as one of the key factors that could positively influence team effectiveness [14]. The knowledge factor would always greatly influence individual performance by measuring working experiences and capability [15]. Furthermore, [14] claimed that factors like leadership, management support, team diversity, reward, and goal clarity would directly affect team efficacy. A reasonable human resource allocation framework was presented with the assignment of human resources for multiple teams formation [16]. However, the optimisation approach utilised was not mentioned, and the limitation was that it did not include important human-related factors such as individual performance.

The genetic algorithm (GA) approach has been widely used in some works related to team or group formation. The Bayesian Network-based Team Formation (BN-TF) was utilised to develop a team in the setting of a business process by applying the problem as a Most Probable Explanation (MPE) [17]. GA was applied with some modifications where the Forward-Backward Greedy GA was developed as the outcome. Two factors were used: handover relation and individual expertise, but the tool to define the degree of these factors were not available.

To assist managers in multiple projects team formation, GA was utilised as a decision-making tool by using the group cohesion factor [18]. The GA showed near-optimal results, which was achieved in a short processing time. Nonetheless, when multiple combinations of employee skills were used, this approach was reported as unsuitable for forming teams dynamically. The decision support system was developed by utilising the fuzzy descriptors to assist the requirement specifications based on the team members' skills [19]. Then, the fuzzy criteria were optimised using GA, and the outcome proved that the decision support system was computationally efficient. Although it was reported to be practical, however, they did not put priority on choosing employees that have high rating values. Moreover, [19] only focused on one factor in team formation: the skills factor.

Silva and Krohling [20] proposed an algorithm based on sociometry to form a team with the human resource as the main factor, by using the fuzzy numbers approach to maximise cohesion. The algorithm allowed the expression of personal preferences provided to the sociometric test. The study reported a promising result where project managers were found to have the potential in using the algorithm as a decision-making tool; however, they overlooked the skills factor. Another limitation was that the part-time employees from the employee database were not considered to be assigned to a group formation. Based on some previous research [8,9,10], the decision-making approach is an important criterion in forming a collaborative team, and many decision-making approaches were discovered.

One of the well-known theories for user acceptance is known as the Technology Acceptance Model (TAM) [21] and further extended by the researchers [22]. Davis et al. [22] suggested two important variables toward the usage of computers: perceived usefulness and perceived use. These two variables are seen as the main variables to affect the results of the user acceptance indirectly or directly [23]. The Unified Theory of Acceptance and Use of Technology (UTAUT) model is another well-known theory used in the study for acceptance and adoption of technology [24]. In comparison to TAM, UTAUT is considered to have a clearer objective to assess the acceptance of technology from the users' point of view [25]. Venkatesh et al. [26] reported that UTAUT performed better than other models in terms of 70% variance in behavioural intention.

UTAUT illustrates a set of factors that influence the user behaviour of acceptance and the behavioural intention towards an information system: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI) and Facilitating Conditions (FC) [14]. Besides that, the UTAUT model recognises four moderators, which influences the relationships between these constructs: Age, Gender, Voluntariness of Use, and Experience. UTAUT was utilised to analyse the proposal for introducing an e-mobile payment service targeted at Brazilian mobile phone users [27], whereas another study employed UTAUT to validate the acceptance of online games [28]. UTAUT was used to evaluate an electronic health record system by looking into factors impacting users' intention to use the system [29]. Howard et al. [30] extended the UTAUT model to further understand the perceptions towards working with building information modelling (BIM). Howard et al. [30] utilised the moderators of experience and voluntariness and, from the results, implied that there was a need to relook at the policies to improve the acceptance towards the BIM.

III. PROPOSED COLLABORATIVE TEAM FORMATION

A. Factors in the Collaborative Team Formation

The identification process and critical evaluations are important for improving the team development process. For the team formation problem, there are a lot of different factors that can be taken into account, where the factors may or may not directly influence the efficacy of the team formed [8]. Table I shows the factors that were identified in some related works. Trust, skills and leadership are important factors in forming a collaborative team to improve team efficiency in organisations. Hence, these three main factors are adopted and incorporated together in this work.

TABLE I. FACTORS IDENTIFIED FOR TEAM FORMATION

Factors	Type of Team and Reference
Leadership and Trust	Exhibitor team [8]
Trust	Virtual team [9]
Trust	Global virtual team [10]
Skill, reliability, and collaboration network	Cross-funtional team [11]
Skill, leadership, reward, management support, team diversity and goal clarity	Technical project team [14]
Human resource allocation	General team formation [16]

The factors, collaboration network and reliability by [11], together with management support, reward, team diversity and goal clarity by [14] were not included in this proposed work as those factors are related to the group as a whole, whereas the focus on this work at this stage is to leverage on the strength of each individual's factor as a contribution to the group formation. Human resources were assigned to form multiple teams but did not focus on individual performance, which was the limitation of the work by [16]. Thus, individual performance is included in this proposed work as it was considered an important factor related to individuals that contributed to a group's efficiency [16].

As a result, together with the three important factors: skills, trust, and leadership, individual performance is included as the fourth factor for the proposed team formation framework. This research presented in this paper consolidates all these four important factors while designing an effective decision-making approach to form a collaborative team.

B. *The Decision-making Approach*

A systematic and accurate decision-making approach to form an effective collaborative team is important to improve team effectiveness. The combination of FL and GA enhances collaborative work in team formation and is based on previous research [19]. FL was shown by [19] as a powerful tool in classifying the imprecise input from skill factor with the manipulation of the FL number (where the process of fuzzification generates the fuzzy set values - between 0.0 and 1.0 in a fuzzy set, denoting different levels or degrees). Meanwhile, GA has been used as an optimisation method for determining the best fitness result in fuzzy criteria.

1) Fuzzy Logic (FL): Extended from a classical set theory, FL handles problems with ambiguous and imprecise data [31]. There are 3 FL concepts 1) Fuzzy set, which allows the FL to set some boundaries, 2) Fuzzy set describes variables with values generated by linguistic variables, and 3) Constraints on the value linguistic variable values by fuzzy set assignment based on distributions of possibility [32]. Before the implementation takes place in the real world, the fuzzy approach supports ambiguity and can be assessed repetitively [33].

2) Genetic Algorithm (GA): GA is one popular approach to solving optimisation problems [34]. Motivated by the natural selection process, GA is seen to be very efficient in solving real-world problems. For example, mixed-integer programming is one of the problems that can be solved using GA [35]. The fitness level is calculated based on the required criteria of the problems' desired requirements. The phases in GA include 1) the initialisation of the population, 2) evaluation of the fitness value, 3) selection, where better results are reported to be achieved with a good selection strategy [36], 4) crossover - a process of recombining parents to have a chance of producing better individuals [37], 5) mutation - an operator that helps to bring some genetic diversity to the chromosome produced [34], 6) repetition of the new population until the best fitness value has been met or the termination criteria achieved.

C. *Fuzzy-GA Approach for the Collaborative Team Formation*

The proposed collaborative team formation has the FL and GA components, which was also used in the model presented by [19]. However, this proposed work is different and extended in terms of 1) determination of the pool of employees, 2) suitable employees are chosen with high rating values, 3) incorporating more factors related to team efficiency, in the team formation.

In this study, the four factors (skills, trust, leadership, and individual performance) were accessed from the employee database, and the fuzzy value properties were derived for each factor. Fig. 1 shows the framework of the proposed decision-making approach, using the FL and GA (Fuzzy-GA). In the project requirements, the inputs may seem to be imprecise; thus, using FL can attain a more robust solution.

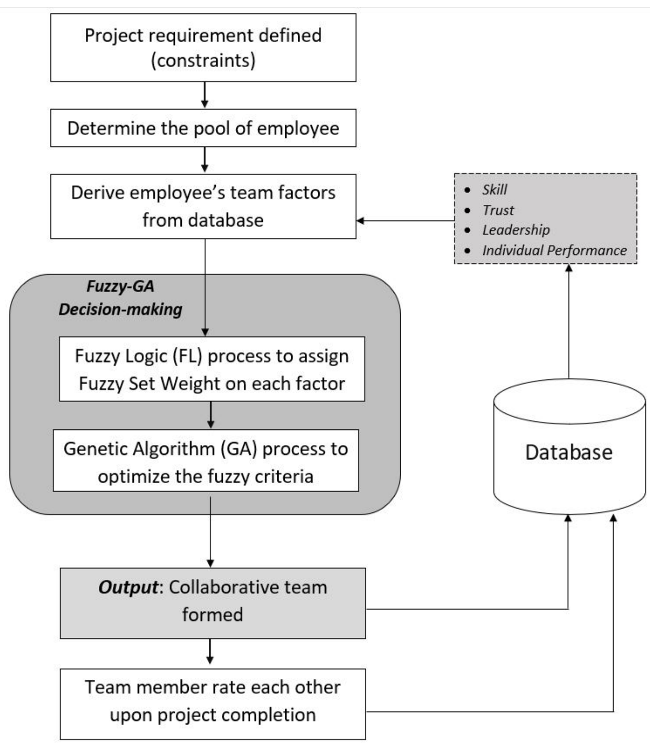

Fig. 1. The Framework of the Fuzzy-GA Decision-making Approach.

First, FL would generate the fuzzy criteria for the factors extracted. Then, the GA would formulate the fuzzy criteria into a fitness value calculation and optimise the solution to form the team. Upon the team formation and completion, the team members would be allowed to rate their other team members based on the skills, trust, leadership and individual performance factors.

D. Fuzzy Evaluation Weight

The selection of team members depended on certain project requirements. Project requirements usually contain ambiguous terms like high, low, medium, easy, or maximum. In this case, FL could help to interpret the ambiguous terms. The method to assign the weight of the fuzzy evaluation is shown in Fig. 2, where the FL approach focused on checking and defining membership set and fuzzy set. This definition is based on trust, skill, leadership, and individual performance factors.

A fuzzy number is derived from a fuzzy membership function A: R → [0, 1], where A has at least a real number in the set of numbers, R; and the elements in R are mapped to the value between 0 and 1 [38]. Thus, to assign the fuzzy number, it needs to be represented by membership sets. The author in [39] utilised the same distribution of fuzzy sets (low, medium and high) for the membership functions, whereas [40] used three fuzzy sets (small, medium, large) in their work. Biswas and Ghosh [41] explained that the fuzzification process can be done by allocating the triangular form of membership functions and that this triangular form is the simplest approach. [41] applied the three linguistic fuzzy sets- which were low, medium and high, as the input parameters and they were equally spaced to make use of the entire input spaces.

In this study, the membership set was categorised as high, medium and low for each factor, as previous researchers [39, 40, 41] had recommended this range to simplify the solution. Table II presents the fuzzy sets for each membership set, for each type of factor, respectively. Each factor had its rating, whether based on category or a range of values**,** to be categorised into the different membership sets, as shown in Table II. Based on the membership set, the fuzzy set weight was assigned, where value 1.0 was assigned for "high", value 0.5 was assigned for "medium", and value 0.1 was assigned for "low".

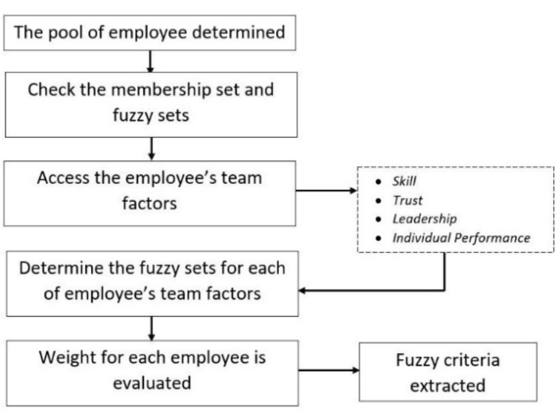

Fig. 2. The Assignment of Fuzzy Evaluation Weight.

TABLE II. FUZZY SETS AND MEMBERSHIP SETS

Factors	**Rating (category/value range)**	**Membership Sets**	**Fuzzy Sets Weight**
Skills	Expert	High	1.0
	Intermediate	Medium	0.5
	Beginner	Low	0.1
Trust	8 – 10	High	1.0
	4 – 7	Medium	0.5
	0 – 3	Low	0.1
Leadership	8 – 10	High	1.0
	4 – 7	Medium	0.5
	0 – 3	Low	0.1
Individual Performance	8 – 10	High	1.0
	4 – 7	Medium	0.5
	0 – 3	Low	0.1

The detailed steps are shown in the pseudocode, as shown in Fig. 3. The project requirements were filtered, and the suitable employee with their rating from the database was determined for each of the four-team factors, f_1 to f_4 (skills, trust, leadership, and individual performance). The steps in FL can be seen from lines 6 to 12. The process continues with the GA approach, which is explained further in the next section.

```
Start
1  Enter Project Requirement, a, b, c
     a = description of project
     b = department involved
     c = number employees
2  Get employee details from database
3  Determine the pool of employees
4    Filter employees that meet at least one condition of constraint a or b
5  Get employee's rating for team factors, f_1^4
6     Fuzzy Logic (FL) starts:
7       Define fuzzy variables
8       Determine fuzzy variables team factors, f_1^4
9       Establish membership set for these variables
10      Generate weight based on fuzzy set
11    Fuzzy criteria extracted
12    FL ends
13    Genetic Algorithm (GA) starts:
14      Generate the initial random population, C_x^y
15      While iteration <= maximum_iteration
16        For each C_x to C_y
17        Identify gene with value "1", G_i to G_n
18           For each gene, G_i to G_n
19              Calculate the gene's fuzzy weight, G_i = Σ f_1^4
20           End for
21        Calculate the fitness for C_x, Fitness_x = Σ_i^n G
22        End for
23        Selection of C_x and C_p2
24        Perform Crossover on C_x and C_p2 if probability 0.95 is accepted
25        New offspring created and chromosomes number updated, C_y++
26        Selection of C_m1
27        Perform mutation if probability 0.5 is accepted
28        Evaluate the pool of C from best to worst until y number of C
29        Generate new population newC_x^y
30        Update C_x^y = newC_x^y
31        Iteration +1
32    End while
33    Return best chromosome, C as the Team Formed
34    GA ends
35 Return Team Formed as the output
End
```

Fig. 3. The Fuzzy-GA Pseudocode for the Team Formation.

E. Optimisation of Fuzzy Criteria using GA

After the FL has generated weights for the four factors based on a fuzzy set using the employee's rating database, the GA would then generate the population of parents as chromosomes. The steps in GA are shown in the pseudocode in Fig. 3 from lines 13 to 34.

For the initial population, *y* number of parent chromosomes, *C* were randomly generated. For this study, *y* = 100, which means there were 100 parent chromosomes, *C* in each generation (iteration). The solution representation of each *y* chromosome, *C* consists of genes of individuals, *G*, where the number of the individuals were based on the number of employees available in the database.

For example, if there are 10 employees, then the size of each chromosome is 10 genes (individuals). Based on the requirements set during the constraint requirement, the number of people formed into a group, *c*, was pre-determined. Thus, during the initial population, the number of genes to be assigned to a group was based on the set constraint. In the solution representation, the genes in the chromosome assigned with value "1" indicate that they were assigned to the group, whereas values "0" indicate that they do not belong. Thus, *n* number of genes, *G*, was assigned with value "1", indicating that there was *n* number of people to be formed into a team.

For example, in the constraint requirement, if the number of people in a group was set to 5, then 5 genes in the chromosome would be randomly assigned with value "1" while others were assigned with value "0". Fig. 4 shows the example of the chromosome representation for the requirements of 5 people to be formed in a group, with 10 people available for the group formation (individuals labelled as A to J). In this example, in the current solution, individual (gene) C, E, G, I and J were assigned with value "1" denoting that they were selected to be in the current group formation.

A	B	C	D	E	F	G	H	I	J
0	0	1	0	1	0	1	0	1	1

Fig. 4. Example of Chromosome Structure for the Solution Representation.

The fitness value of the current chromosome solution (parent) would be calculated based on the genes assigned to value "1" in the current solution. The fitness calculation for the *i*-th individual gene assigned to value "1", G_i, is shown in Equation (1). The fuzzy weight values generated based on fuzzy set for each factor, f_1 to f_4 (skill, trust, leadership and individual performance) for the *i*-th individual, are added as the total weight for the G_i. Assume that there was *n* number of people set to be in the group formation in the constraint requirement. Therefore, there would be *n* number of people to be assigned with the value "1". The overall fitness value for the current solution, *x*, ($Fitness_x$) would be calculated, where the gene values from $individual_i$ to $individual_n$ were summed together, as shown in Equation (2).

$$G_i = \sum f_1^4 \quad (1)$$

$$Fitness_x = \sum_i^n G \quad (2)$$

Then, GA would proceed with the crossover and mutation process to produce new offspring from the pool of parents. A high crossover rate is usually used as it was reported to have good results on the optimisation process. Following the suggestions by [42] and [43], a crossover rate of 0.95 was applied. For the mutation rate, the suggested value of 0.5 by [44] was adopted as this was reported to have a better solution quality. Thus, crossover and mutation were implemented, and then fitness was calculated again for the newly formed offsprings and parents. The new generation was produced with a selection of 100 chromosomes with the best fitness values, replacing the 100 parent chromosomes in the previous generation. This process was repeated until the highest fitness score was converged or reached the stopping criterion. Finally, a group was formed with the best fitness value and produced as an output of the collaborative team formation.

IV. User Acceptance Survey on the Proposed Collaborative Team Formation

This section presents the development of the case study, the Unified Theory of Acceptance and Use of Technology (UTAUT) framework, and the data collection details. The case study was created to produce an artefact to be evaluated by the respondents. To evaluate the user acceptance, a survey was carried out, and the UTAUT model was used. Thus, the details of the framework and the hypothesis created are presented in this section.

A. Development of the Case Study

To study the user acceptance of this framework, a case study was constructed based on the team formation with the requirements of five employees to complete a project. The case study for this proposed framework was on the collaborative team formation in IT Department that required experts with a specification in UNIX server programming. The rules were defined for extraction using the standard format for project requirements. While this example was drawn from the IT department of an organisation, a similar practice can extend to all kinds of organisations with different project member requirements. This case study was built to be used as an artefact in the survey of user acceptance using the UTAUT questionnaire.

In this case study, the project required people who have skills in UNIX programming. The employee's database had already been assigned with values in the four factors of the Fuzzy-GA collaborative team formation. The four factors were derived for the FL process. From the rating values of the employees for each factor, FL generated the final weight using the membership set and fuzzy set. The case study followed the Fuzzy-GA collaborative team formation steps as presented in Section III. The example of this case study was developed as a prototype and produced as an artefact to be evaluated using the UTAUT survey for user acceptance.

B. Development of Unified Theory of Acceptance Framework

UTAUT is an acceptance model that justifies the information system's usage and intention by the user [24]. The proposed framework in this research was validated based on UTUAT model using a questionnaire survey method. Fig. 5 shows the framework of the user acceptance model proposed in this study. Six variables were involved, with the primary variable being the dependent variable, the Behavioural Intention (BI). BI variable denotes a person's intention to use technology, and in this case - the intention to use the Fuzzy-GA collaborative team formation system. The UTAUT framework proposed in this study predicted that BI could be influenced by four independent variables: Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI) and Facilitating Conditions (FC).

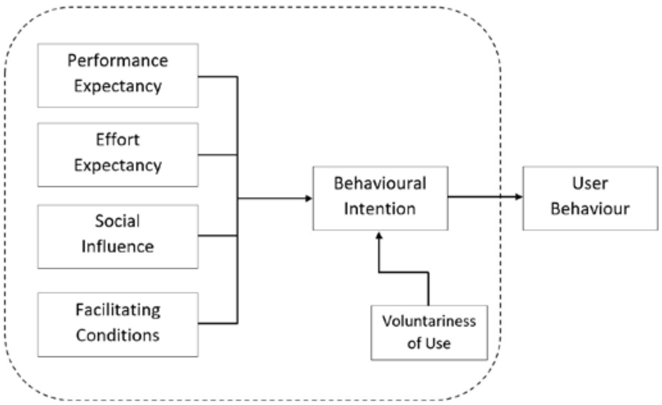

Fig. 5. User Acceptance Model Framework based on UTAUT.

In this study, one variable acted as the moderator from the UTAUT model, which was the Voluntariness of Use (VU). VU explores the extent to which an individual or an organisation believes that the acceptance or the use of new technologies happens voluntarily [45].

Hence, in this study, the VU evaluated the employee's readiness towards the collaboration team formation based on the Fuzzy-GA approach, whereby the more voluntarily a person wanted to use the proposed system, the higher the person's intention was to use the system. When automated team formation is to be implemented in an organisation, it may be a part of the requirements that the employees need to use the system. However, if they are not required to use the system, the question lies if they may still intend to use the proposed system. Therefore, the VU moderator was included in this study to find out the employees' level of voluntarism to use this proposed system. Based on the model proposed, the following hypotheses were established for this study:

- Hypothesis 1 (*H1*): PE has a positive effect on individual BI to use the Fuzzy-GS collaborative team formation system.
- Hypothesis 2 (*H2*): EE has a positive effect on individual BI to use the Fuzzy-GS collaborative team formation system.
- Hypothesis 3 (*H3*): SI will exert a positive influence on individual BI to use the Fuzzy-GS collaborative team formation system.
- Hypothesis 4 (*H4*): FC has a positive correlation with individual BI to use the Fuzzy-GS collaborative team formation system.
- Hypothesis 5 (*H5*): VU is positively related to the individual BI to use the Fuzzy-GS collaborative team formation system.

The development of hypotheses H1, H2, and H3 was supported by [46], where the constructs of PE, EE and SI were used to investigate the acceptance (BI) of the respondents to their virtual team framework in a learning environment. In [47], it was reported that the attitude towards the intention to use could be influenced by SI and FC, where FC was seen to be instrumental in empowering the individuals to have positive acceptance of the technology. Hence, this supports the hypothesis H4 tested in this study. In [45], the work had predicted the negative impact of VU on BI. However, in this study, the VU was investigated to find the positive impact on BI. The focus was to verify whether the respondents were inclined to voluntarily accept the technology.

C. Data Collection

Based on the UTAUT model framework in Fig. 5, a Likert-scale questionnaire was used to collect data on the acceptance of IT department employees towards the proposed Fuzzy-GA approach for collaborative team formation in an organisation.

The questionnaire and the artefact for the collaborative team formation framework were distributed to the respondents, who are employees of an organisation in Penang, Malaysia. The data was used to analyse the technology acceptance by the organisation's employees. The constructions of the questions are shown in Table III.

TABLE III. THE CONSTRUCTION OF QUESTIONS

Construct	**Item**	**Questionnaire item**	**Cited from**
Performance Expectancy	PE1	I would find the Fuzzy-GA collaborative team formation system as useful in my job.	[30]
	PE2	Using Fuzzy-GA collaborative team formation system will enable me to accomplish my job more quickly.	[41]
	PE3	Using Fuzzy-GA collaborative team formation system will increase my productivity.	
	PE4	Using Fuzzy-GA collaborative team formation system will improve my performance in my job	
Effort expectancy	EE1	It will be easy for me to become skilful at using the Fuzzy-GA collaborative team formation system.	[30]
	EE2	Learning how to use Fuzzy-GA collaborative team formation system will be easy for me.	[41]
	EE3	I understand clearly on how to use the Fuzzy-GA collaborative team formation system.	
	EE4	I do not have any difficulties in explaining why using Fuzzy-GA collaborative team formation system may be beneficial.	
Social influence	SI1	People who influence my behavior think that I should use Fuzzy-GA collaborative team formation system.	[41]
	SI2	People who are important to me think that I should use Fuzzy-GA collaborative team formation system.	

	SI3	The organisation has supported to use Fuzzy-GA collaborative team formation system.	[30]
Facilitating conditions	FC1	I have the necessary resources to use Fuzzy-GA collaborative team formation system.	[41]
	FC2	I have the necessary knowledge to use Fuzzy-GA collaborative team formation system.	[30]
	FC3	A specific person or specific group is available for assistance if there are difficulties concerning the use of Fuzzy-GA collaborative team formation system.	[41]
Behavioural intention	BI1	I intend to use Fuzzy-GA collaborative team formation system in the future.	[41]
	BI2	I predict that I will use Fuzzy-GA collaborative team formation system in the future.	
	BI3	I plan to use Fuzzy-GA collaborative team formation system in the future.	
Voluntariness of use	VU1	Although it might be helpful, using Fuzzy-GA collaborative team formation system is certainly not compulsory for my job.	[41]
	VU2	My use of Fuzzy-GA collaborative team formation system data is voluntary.	

V. Result and Discussion

During data collection, the artefacts were presented to the respondents, and the questionnaires were answered. In this section, the results from this data collection are presented. The survey was conducted to study the user's acceptance of the proposed Fuzzy-GA collaborative team formation system. With the help of the UTAUT framework, the results projected the respondents' intention to use the proposed system as a decision support system for collaborative team formation.

A. Data and Descriptive Analysis

As mentioned in Section VI-C, the five-point Likert scale was used, representing Strongly Disagree to Strongly Agree. 70 questionnaires were administered, and a total number of 50 were returned, with a response rate of 71%. The statistical tool, SPSS 24, was applied to capture and analyse the data from the questionnaire. Table IV shows the descriptive statistics for the UTAUT constructs from the response to each question. The mean values for PE, EE, SI, FC and VU were between 3 and 4, implying that most responses from the respondents were somewhat Neutral and Agree.

B. Pearson's Correlation

Pearson's Correlation was employed to define the strength of the relationship between two variables. Table V presents the range and categories of Pearson's Correlation coefficient strength described by [37], which was used as a benchmark of the relationship strength.

To investigate the acceptance of the proposed collaborative team formation approach, the impact of the UTAUT constructs of the independent variables, PE, EE, SI and FC towards the dependent variable, BI and the employee's readiness for the VU towards BI were evaluated. Table VI shows the result based on Pearson's Correlation analysis.

TABLE IV. Descriptive Statistics

Code	***Minimum***	***Maximum***	***Mean***	***Std. Deviation***
Performance Expectancy (PE)				
PE1	2	5	4.13	.730
PE2	2	5	3.77	.858
PE3	2	5	3.80	.961
PE4	2	5	3.93	.785
Effort Expectancy (EE)				
EE1	3	5	4.00	.788
EE2	2	5	4.10	.923
EE3	2	5	3.87	1.137
EE4	2	5	3.67	.994
Social Influence (SI)				
SI1	2	5	3.47	.819
SI2	2	5	3.57	.858
SI3	2	5	3.90	.803
Facilitating Conditions (FC)				
FC1	2	5	3.80	.805
FC2	2	5	3.93	.785
FC3	2	5	3.50	1.009
Behavioural Intention (BI)				
BI1	2	5	3.83	.950
BI2	2	5	3.83	.986
BI3	2	5	3.87	.973
Voluntariness of Use (VU)				
VU1	1	5	3.67	1.155
VU2	2	5	3.67	.758

TABLE V. The Range and Categories of Pearson's Correlation Coefficient Strength [37]

Range Value	**Category of the Relationship Strength**
0.50 -1.0	Strong
0.30-0.49	Moderate
0.10-0.29	Weak

TABLE VI. Pearson's Correlation Results for All Variables

	M_PE	***M_EE***	***M_SI***	***M_FC***	***M_BI***	***M_VU***
M_PE	1	.739**	.780**	.752**	**.785****	.023
M_EE	.739**	1	.852**	.879**	**.790****	.114
M_SI	.780**	.852**	1	.835**	**.858****	.204
M_FC	.752**	.879**	.835**	1	**.784****	.172
M_BI	.785**	.790**	.858**	.784**	1	.214
M_VU	.023	.114	.204	.172	**.214**	1
**. Correlation is significant at the 0.01 level (2-tailed).						

C. Hypothesis Evaluation

In this section, the five proposed hypotheses are evaluated. The correlation values to validate these hypotheses can be referred to in Table VI.

Table V is used as the reference to determine the strength of the relationship between two variables in each hypothesis.

- Hypothesis 1: The Pearson's correlation value for mean PE (M_PE) to mean BI (M_BI) was 0.785. Thus, PE had a strong positive effect on individual BI. Hence, hypothesis *H1* was supported.
- Hypothesis 2: The Pearson's correlation value for mean EE (M_EE) to mean BI (M_BI) was 0.790. Thus, EE had a strong positive effect on individual BI. Hence, hypothesis *H2* was supported.
- Hypothesis 3: The Pearson's correlation value for mean SI (M_SI) to mean BI (M_BI) was 0.858. Thus, SI has a strong positive influence on individual BI. Hence, hypothesis *H3* was supported.
- Hypothesis 4: The Pearson's correlation value for mean FC (M_FC) to mean BI (M_BI) was 0.784. Thus, FC had a strong positive correlation with individual BI. Hence, hypothesis *H4* was supported.
- Hypothesis 5: The Pearson's correlation value for mean VU (M_VU) to mean BI (M_BI) was 0.214. Thus, VU had a weak positive correlation BI. Hence, hypothesis *H5* was not supported.

D. Discussion

As mentioned previously, the Pearson's Correlation results for all the variables tested are shown in Table VI. The relationship of the first independent variable, Performance Expectancy (PE) to the Behavioural Intention (BI) can be interpreted from the mean PE to mean BI correlation value, where the value was 0.785. For the next independent variable, Effort Expectancy (EE), the correlation value of mean EE (M_EE) to mean BI (M_BI) was 0.790.

Next, the relationship of the independent variable Social Influence (SI) with BI can be referred to where the mean SI (M_SI) to mean BI (M_BI) had the correlation value of 0.858. For the last independent variable, Facilitating Conditions (FC), the correlation value of mean FC (M_FC) to mean BI (M_BI) was 0.784.

Referring to the benchmark value shown in Table V and the Pearson's correlation values of the independent variables PE, EE, SI and FC to the dependent variable BI, the values were within the range of 0.5 – 1.0. This shows that there were strong relationships and positive effects between those independent variables with the BI. Therefore, the survey showed that the employees (respondents) were positive towards accepting the proposed Fuzzy-GA-based decision-making approach for collaborative team formation, where their intention to use the system was high.

Currently, limited research applied UTAUT to investigate the acceptance towards collaborative team systems. Thus, this study was motivated to investigate the level of acceptance towards a collaborative team system using the UTAUT construct, as previous researchers [25,26] reported the advantage of UTAUT compared to other models such as TAM. Because of the limitations, comparisons were made with other studies that used UTAUT for acceptance towards technology in general.

The work by [46] explored acceptance towards virtual teams but focused more on the learning environment using the UTAUT. The author in [46] investigated variables PE, EE, SI and FC towards the BI. In their findings, PE, SI and FC had a positive impact on BI, which coincides with the result achieved for the same variables in this study.

However, in [46], EE did not have a positive impact on BI. On the contrary, this study found EE to have a favourable result to BI, where it had the second-highest correlation to BI. This may be due to the respondents finding that the artefact of the system seemed to be understandable and simple to be used if implemented. Thus, not much effort is required to adapt to the new system.

In [47], the researcher carried out an extensive review on the acceptance level of teachers and students on computer- and technology-based education systems. From the systems reviewed for the year 2017 to 2020 in [47], there were 16 works reviewed that used all four variables (PE, EE, SI and FC) in their studies. In that 16 works, each of the variables that had a direct or positive impact on BI were reported as such 1) PE - 15 direct impacts, 2) EE - 12 direct impacts, 3) SI - 11 direct impacts, 4) FC - 10 direct impacts, where one study had shown a very significant impact of FC compared to other variables. In this paper, the most significant variable was found to be SI.

In this study, from the strong relationship of PE to BI, it can be deliberated that the respondents had a positive expectancy that using the proposed system, if implemented in the organisation, can somehow help their tasks be completed more efficiently and increase their productivity.

The relationship of EE to BI was also strong; thus, the respondents would have no problem making an effort to use the system. The correlation value of the relationship of FC to BI was slightly lower compared to the other independent variables but was still in the range of a strong relationship. Hence, this implies that the respondent believed that there would be enough facilitating resources and help when using the proposed system.

The independent variable SI had the strongest positive correlation with BI as it had the highest correlation value. This shows that employees can be influenced by their social peers and networks towards accepting the proposed collaborative team formation. This demonstrates the importance of social influence among the employees when adopting new technology within their working environment.

Although the independent variables all showed positive effects towards intention to use the proposed system that was not the case with the moderator variable, Voluntariness of use (VU). For the moderator VU, the value of Pearson's Correlation for mean VU (M_VU) to mean BI (M_BI) was only 0.214. This is in the range of 0.00 – 0.29, as shown in Table V, which indicates a weak relationship.

The value shows that the VU was negatively related to BI. This coincides with the result achieved by [45] that had predicted there would be a negative impact of VU towards BI. Even in the study by [48] that reported VU had a positive impact on BI and other independent variables, the VU was negatively correlated to the user behaviour.

From the findings in this study for moderator VU, the negative correlation may have occurred because the employees were not ready to voluntarily transform the manual collaborative team formation into an automated collaborative team formation. They might have the intention to use it if it was made compulsory by the organisation and also had a positive attitude in their intention to use the system, but they were not inclined towards using it voluntarily.

VI. Conclusion

This research studied the user's acceptance of the proposed framework for organisational collaborative team formation by incorporating the Fuzzy-GA approach and integrating four factors that influence team formation: leadership, trust, skills and individual performance. FL was utilised to assign a detailed weight for the four team formation factors as fuzzy attributes. Then, GA was applied to optimise the fuzzy attributes. The acceptance of users to the Fuzzy-GA collaborative team formation was evaluated by using the UTAUT survey, and the results were presented.

The results from the analysis showed that the organisation's employees accept the proposed Fuzzy-GA based approach on collaboration team formation based on the positive Behavioural Intention (BI) on the Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI) and Facilitating Conditions (FC). This shows that the employees tend to accept the use of the system if it were to be imposed on them. Thus, this proposed framework is believed to be capable of forming a high visionary workforce while improving team performance at all levels. Looking at the positive outcome from the variables PE, EE, SI and FC, in the results of the user acceptance study, this proposed study is seen to have the potential to be implemented in organisations.

However, the employees were not ready to voluntarily transform towards an effective collaborative team formation, shown from the low coefficient strength of Pearson's Correlation analysis on Voluntariness of use (VU). From this finding, although they might intend to use it if it was made compulsory or found it helpful in project completion, they might not be ready to adapt to the system voluntarily. This may be because this type of system was still new to them, and they were not familiar with it. Hence, this paper can serve as a reference for potential top management in organisations that intend to adopt a similar automated collaborative team formation to strategise a better approach to increase their employees' voluntary involvement in such a system.

In future work, the rating component of the Fuzzy-GA collaborative team formation can be further expanded. The team members rating from the successfully formed team and implemented project can be reused. Thus, a new project requirement can be added, for example, experience in successful team formation for future team formation consideration. Besides that, the future work for the Fuzzy-GA collaborative team formation will focus on the improvement and further evaluation of the Fuzzy-GA efficiency especially on the optimisation of the group formation. The Fuzzy-GA will be considered for further enhancement by tuning the GA component of the framework. For example, the Fuzzy-GA approach can be hybridised with other metaheuristic algorithms such as simulated annealing or ant colony optimisation.

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Secured SECS/GEM: A Security Mechanism for M2M Communication in Industry 4.0 Ecosystem

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***Abstract*—The manufacturing industry has been revolutionized by Industry 4.0, vastly improving the manufacturing process, increasing production quality and capacity. Machine-to-Machine (M2M) communication protocols were developed to strengthen and bind this ecosystem by allowing machines to communicate with each other. The SECS/GEM protocol is at the heart of the manufacturing industry, thriving as a communication protocol and control system for years. It is a manufacturing equipment protocol used for equipment-host data communications. However, it is not without drawbacks, despite being a widely adopted communication protocol used by leading industries. SECS/GEM does not offer any type of security features as it was designed to work in a closed network. Such shortcomings in the protocol will allow attackers to steal secrets such as manufacturing processes by looking at recipes, perform reconnaissance prior to sabotage attempts, and can have severe implications on the entire industry. This paper proposes a mechanism to secure SECS/GEM data messages with AES-GCM encryption and evaluate the performance with the standard SECS/GEM protocol. The results from our evaluations showed that the proposed mechanism achieves data confidentiality and authenticity with a negligible overhead of 0.8 milliseconds and 0.37 milliseconds when sending and receiving a message, respectively, compared to the standard protocol.**

***Keywords*—SECS/GEM; HSMS; cybersecurity; industry-4.0; machine-to-machine communication; AES-GCM**

I. Introduction

Industry 4.0 is bringing forth significant changes to the manufacturing industry. Industry 4.0 aims to take the manufacturing industry to the next level of technological advancement for an interconnected manufacturing ecosystem where machines communicate through the network to exchange messages, instructions, and data. With sophisticated machinery and automation, more integrated machine-to-machine communication, real-time monitoring and data collection, machine learning, and enhanced inter-connectivity, Industry 4.0 is changing the existing manufacturing process for the better and improving overall production [1]. As machines are interconnected, they generate activity analysis, predictive diagnostic data, performance statistics, and other monitoring and control information. Thus, real-time decisions can be made quickly with advantages such as time and cost-saving. In many circumstances, human interaction will be removed from the factory environment. With predefined and maintained settings and parameters, the factory equipment can make crucial decisions by itself, ensuring maximum cost-effectiveness for the industry.

Industry 4.0 deals with large volumes of data. Therefore, data security is a major concern when trying to achieve the true potential of Industry 4.0. It is essential to implement end-to-end encryption to fix vulnerabilities against various attacks [2]. With Industry 4.0's increased data density and the convergence of information and operational technologies, new issues emerge, particularly in the field of cybersecurity [3]. Cybers-attacks are the most critical problem that all countries are concerned about. It is a method of safeguarding digitally stored corporate data and valuable information about a system or subject from misuse, unauthorized access, and theft. Cyberattacks have become more common as network connections have grown, owing to a growing tendency to exploit data for various reasons, including financial gain and strategic reasons [4]. It is especially true in the case of cyberattacks against the manufacturing industry.

Although the manufacturing industry has been gradually updating and improving its IT security over the years, it can be seen in the Verizon Data Breach Investigation Report 2019, detailing 352 cyberattack incidents, out of which 87 were against the manufacturing industry. Recent attacks and security breaches against the manufacturing industry are alarming, making it a highly targeted and vulnerable entity for attackers [5]. A survey by the Engineering Employers' Federation (EEF) shows that 60% of manufacturers were victims of cyberattacks at some point in time, and one-third of the affected manufacturers have suffered financial losses and market loss. A 2021 study by Cybersecurity Ventures predicts that corporations worldwide will suffer losses up to $10.5 trillion yearly by 2025 resulting from cyber-attacks, estimated in 2015 to be $3 trillion [6]. The cyberattack on Taiwan Semiconductor Manufacturing Company (TSMC) was in Taiwan's history, the worst data security infringement to befall them. It completely exposed data security vulnerabilities at TSMC's production foundries. These cyber-attack incidents are happening as the manufacturing industry embraces the shift to Industry 4.0, with more and more machines becoming connected for communications and automation [7].

The SECS/GEM protocol is at the heart of the semiconductor industry in companies such as Intel, Samsung, TSMC, IBM, Qualcomm, and many more [8]. It has been profoundly used as a Machine-to-Machine (M2M) communication protocol and control system for decades. The SECS/GEM protocol is a specially designed semiconductor

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manufacturing equipment protocol used for equipment-host data communications.

A study by A. Laghari et al. [8] reveals that although SECS/GEM has been widely adopted and is critical to the semiconductor manufacturing industry, it is not without drawbacks. It does not offer any type of security features. It uses binary encoded messages to communicate between machines, making it open for anyone on the network to read the data; thus, data confidentiality is lost. Attackers on the network can modify data inside the messages as there are no authenticity checks. SECS/GEM protocol standards were designed in an era where machines were not required to be connected to the network [9]. The machines were initially expected to be working behind an air-gapped network and therefore did not require security features like network and data security. Thus, the focus was only needed on physical security. With Industry 4.0, the machines are required to be connected to the network for accessing data, analysis, and much more. These requirements open up air-gapped networks, and hence, the attack surface is enlarged in the process. Thus, cybersecurity in the manufacturing ecosystem is of the most importance. Data confidentiality, authenticity, and availability in machinery connected to the industrial network are all considered in the context of cybersecurity [10]. SECS/GEM is susceptible to these issues since it does not provide any kind of security features.

As SECS/GEM is a widespread M2M communication protocol used all around the world, we cannot simply introduce a new protocol. This paper proposes a security mechanism for the SECS/GEM protocol to attain data confidentiality and authenticity in SECS/GEM communications. We propose to encrypt the data payload of SECS/GEM messages to protect the data from attackers. In addition, we propose to use a hash-based tag to verify message data authenticity to ensure data has not been modified or corrupted by attackers.

To our knowledge, no prior research has been done on the security aspects of the SECS/GEM protocol. Hence, this is a novel field of study and has no known related works for comparison.

The rest of the paper is structured as follows. In Section II, the SECS/GEM protocol standards are described briefly. Section III discusses the security issues found in SECS/GEM protocol standards. In Section IV, we present the proposed mechanism in detail. Section V presents the implementation and testbed details. In Section VI, we present our evaluation and results for the proposed mechanism. Section VII concludes this work and discusses future work.

II. SECS / GEM PROTOCOL STANDARDS

SEMI (formerly Semiconductor Equipment and Materials International) has released five major protocols over the years. With the first release in the year 1978 and the latest revision being released in 2020. Though the SECS/GEM communication protocols were published two decades ago, they are regularly maintained and published. This section is an overview of the major SECS/GEM protocol releases. Table I gives a brief description of SECS/GEM standards.

TABLE I. SECS / GEM PROTOCOL STANDARDS

Year	SEMI Standard	Description
1978	**E4** SECS-I	**SEMI Equipment Communications Standard-I** protocol allows various equipment and a host to communicate over an RS-232 connection.
1982	**E5** SECS-II	**SEMI Equipment Communications Standard-II** facilitates data exchange between equipment and host as a specific stream and function message in a predefined format.
1992	**E30** GEM	**Generic Equipment Model** aids in specifying usage of any particular SECS-II message as well as the monitoring of equipment behavior when communicating with the host
1994	**E37.1** HSMS-SS	**High-Speed SECS Message Service – Single Session** is a TCP/IP-based communication protocol that manages a single machine-to-machine communication link between equipment and a host.
1994	**E37.2** HSMS-GS	**High-Speed SECS Message Service – Global Session** is an extension to E37.1 with handling multiple sessions and maintaining the state of the equipment as an additional feature.

A. SEMI Equipment Communications Standard-I

The SEMI Equipment Communications Standard-I (SECS-I), also referred to as SEMI E4 standard, is the oldest SECS/GEM standard. The exchange of communication messages between manufacturing equipment and a host computer is described in this standard. The equipment and host are not required to be familiar with one another to exchange messages [11] [12]. The SECS-I standard uses the RS-232-c standard for communication. Over RS-232, the SECS-I has a sluggish data transfer rate and does not offer support local area networks based on TCP/IP. The messages and data are exchanged asynchronously. The connection is bidirectional but limited to work in half-duplex mode. The rate of communication is generally between 9,600 baud and 19,200 baud. The protocol uses 256-byte blocks for multiblock data transfers. However, longer distances are not suitable for RS-232 transmission, and it has a low noise immunity. SECS-I is only used in old legacy production machinery and is not used in any newer machinery.

B. SEMI Equipment Communications Standard-II

The SEMI Equipment Communications Standard-II (SECS-II), also referred to as SEMI E5 standard, is a communication protocol that defines a generic messaging layer to send or receive any given data structure supported by the standard. Additionally, it specifies a collection of standard messages, each with its purpose, structure, and identity. It decodes the message type, message structure, data types, and message contents sent between the manufacturing equipment and the host. The message types are specified for various categories that cover a wide range of functions, generic as well as for specific purposes. The messages are divided into streams based on the particular category the message falls into (e.g., equipment status is dealt by Stream-1, whereas recipe management specifications are handled by Stream-7, etc.), with functions being individual messages within each stream [13].

The streams and functions are represented by numbers of size 1 byte. Since only one byte is used, the numbers start from 0 and can go up to 255. The combination of stream and function numbers can be represented as SnFm, wherein n represents stream number and m represents function number designated for data exchange. The request messages are represented by odd-numbered function codes, whereas response messages are represented with even-numbered function numbers. For example, a request message of Stream 1 and Function 13 (S1F13) is an "Establish Communication Request" message for a host/equipment. Upon receiving an S1F13 message, the equipment/host would send a stream-1 and function-14 (S1F14) message as a reply. A request message and its corresponding response message are called a transaction (i.e., S1F13/S1F14). A unique ID is assigned to each transaction. The sender specifies the SystemBytes, a field in the message header of size 4 bytes. The SystemBytes is used to link a request message with the respective response message.

The SECS-II standard provides data types for encoding data in a compact, bandwidth-efficient format. Integers, both unsigned and signed, can be stored in 1-byte, 2-byte, 4-byte, and 8-byte sized fields. Floating-point values can be stored in fields of size 4 and 8 bytes. On/off, values are represented using the 01-byte Boolean data type. Strings are described using the ASCII data type, while file data such as images and statistical plots are stored using the binary datatype. The List data item type can contain nested lists as well as a sequence of other primitive data items. The total number of items in a list is obtained from the length bits of the List data item. The maximum size for a data element within a SECS-II message is 16,777,215 bytes (approximately 16.5MB) long, according to the E5 standard. A message could contain only one single data element (for example, binary data or encoded text), or a large, sophisticated data structure (for example, lists stored within another list), or even no data at all.

C. Generic Equipment Model

The Generic Equipment Model (GEM), also referred to as SEMI E30 standard, defines a set of minimum requirements for describing factory equipment using a generic model, as well as optional features, use cases, and scenarios. A subset of SECS-II messages is used in the GEM model [14]. The GEM interface includes basic requirements as well as additional equipment capabilities. The GEM standard defines the generic model for equipment so that whatever the scale or sophistication of the production equipment, a generic interface (GEM) can be implemented for it. Some basic equipment, for example, does not require recipe management because it does not have any recipes for processing. For complex equipment, having many recipes to pick from, the requirement is that it must push/pull recipes to and from the host machine. GEM is also scalable in terms of data size. Simple devices with limited capabilities, for example, may publish a dozen different collection events. On the other hand, complex factory equipment may generate large amounts of events and data and publish many collection events in a short period. Yet, both can use the same GEM interface.

D. High-Speed SECS Message Service

High-Speed SECS Message Service (HSMS), also referred to as SEMI E37 standard, is a SEMI standard that defines the transport protocol for SECS/GEM message communications [15] [16]. HSMS is based on TCP/IP. It is, in fact, a derivation of TCP/IP with minor modifications and employs nearly the same techniques for creating connections as specified in RFC 793 [17]. One such change is that RFC 793 specifies to allow the communicating parties to connect to each other simultaneously. The HSMS protocol, on the other hand, restricts the connection-establishment procedure and defines two separate modes to establish connections, the passive and active modes. Devices running active mode can only initiate a request to establish a connection. The devices in passive mode can only accept connection establishment requests from other devices in active mode. HSMS carries SECS-II messages in binary encoding format to monitor status, control processes, report on events, and perform numerous other machinery operations after a communication link between equipment and host has been established. Between the communicating entities, the established connection is maintained for as long as required. Messages are exchanged between equipment and host until either device disconnects for some reason, such as hardware/software upgrades, machine additions or removals, or maintenance. The messages are sent as a data stream with a fixed header structure. The header fields are described in Table II. The first 4 bytes determine the encoded SECS-II message's total length, including the size of the header (10 bytes). The smallest HSMS message is 10 bytes (i.e., just the header size), while the largest conceivable size of the message is 4 GB. The structure of a HSMS message is depicted in Fig. 1.

TABLE II. HSMS HEADER FIELDS

Header Field	***Size***	***Description***
Session ID	2 bytes	It is used to associate reference between control messages and subsequent data messages
Stream	1 byte	Represents the Stream number of the message
Function	1 byte	Represents the Function number of the message
PType	1 byte	It is an enumerated type to define encoding used. HSMS defines PType with value zero to mean SECS-II message encoding. Non-zero PType values are reserved for subsidiary standards' future use.
SType	1 byte	It is an enumerated type to identify if the message is a control message (non-zero) or a data message (zero)
System Bytes	4 bytes	It is used to associate primary messages with the respective secondary message (reply)

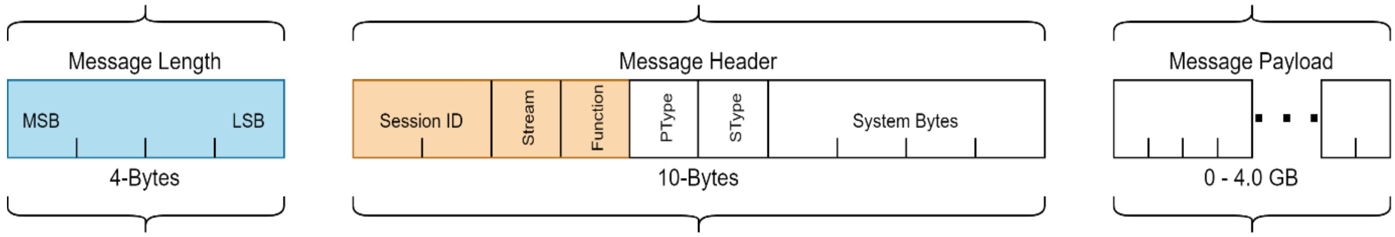

Fig. 1. Standard HSMS Message Structure.

The SECS/GEM interface allows factory hosts to monitor equipment actions and provides total equipment control. Everything happening on the machinery can be monitored, and enhanced logic can be put on the equipment to make better decisions. Various applications can be implemented using SECS/GEM to monitor and analyze statistical data, troubleshoot, predict possible maintenance requirements, control processes for feedback/feedforward, check usage, track materials, validate recipes, etc. These systems also eliminate the requirement for an operator-to-equipment interaction, resulting in fewer operators needed in the production environment. Factories can reduce material scrap and waste by using effective recipe management. For example, storing golden recipes in a centralized location via the SECS/GEM interface makes sure that the right recipes and materials are used.

III. Security Issues

The SECS/GEM protocols in its original standard do not specify any encryption for its message data and all messages between equipment and host are unencrypted binary encoded data. This shortcoming introduces opportunities for attackers to exploit and disrupt the health of the production environment. Attackers can launch attacks, disrupt communications, steal intellectual property belonging to the company, and more.

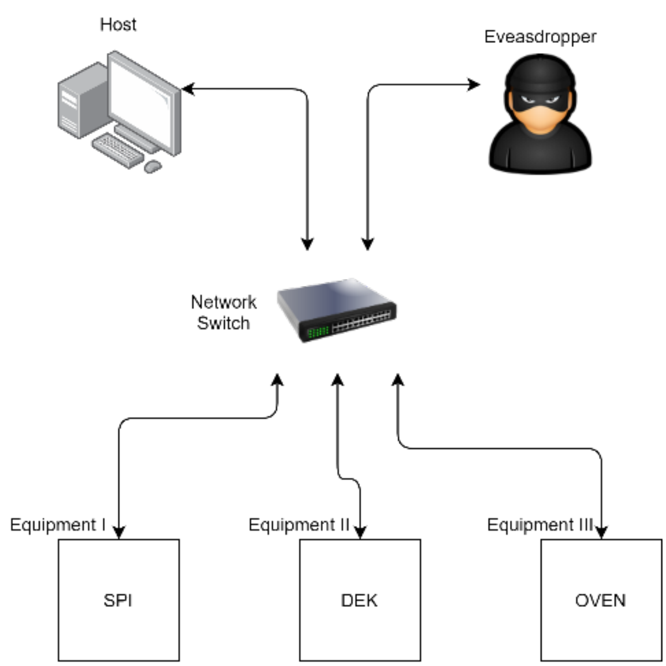

Fig. 2. Attacker on the network Eavesdropping Communications.

In this paper, we focus on data confidentiality and authenticity issues in SECS/GEM protocols. Due to data being transferred in binary encoded format, attackers can eavesdrop on equipment-host communication and lead to loss of data confidentiality. Fig. 2 shows how an attacker may position themselves on the network to eavesdrop on communication messages passively. Attackers can learn machine parameters and settings, product design information from communication messages. Intellectual property such as product designs, parameters, and settings for the manufacturing process can be stolen by attackers for monetary gain. Such an attack can be a life-or-death situation for companies as the industry is always competitive, and loss of IP can cost a company their leadership in the industry.

A study by A. Corallo et al. [10] shows that if a product's design information is no longer confidential, it could negatively affect the company's competitive advantage. The loss of unique knowledge about the items and their manufacturing methods may work in competitors' favor. Data confidentiality of machine settings and parameters or machinery status, if lost, could lead to a decline of the company's reputation. This information provides insight into the production ecosystem's health. Therefore, if sensitive information such as machine malfunctions are revealed, the company's reliability would be questioned and could lead to investors leaving and losing customers. The loss of confidentiality of product properties, like quality indicators, would negatively affect the company's leadership and change in favor of its competitors. In fact, in the event of a product fault, competitors may exploit the situation by using ad hoc styled marketing strategies to win a larger market share.

Attackers can also launch tailored attacks such as Man-In-The-Middle (MITM) attacks to disrupt production and cause financial losses as part of sabotage operations. Such attacks can range from disrupting communications, injecting false data, causing machine failures, etc. It is easy for attackers to launch such attacks as current SECS/GEM protocol implementations do not provide data confidentiality or perform authenticity checks on the data.

To further discuss the seriousness of this issue, consider the scenario where an attacker launches a passive eavesdropping attack on the network and listens to communications. Over time the attacker can gather enough data about the machine settings and parameters to launch MITM attacks. For example, attackers may learn parameters that can make machines run differently, cause malfunctions or create defective products that fail quality checks. Such knowledge will let attackers launch attacks that will look normal to the system and intentional disruptions of the manufacturing systems. Attacks of this kind can cause failure rates to be high and make it look like the machines malfunction or fail even when they are not. This type of attack is proven to be possible.

The infamous STUXNET virus is a real-life example of the previously described scenario which targeted the Iranian nuclear program and caused equipment to malfunction [18], [19]. The STUXNET virus had the pattern described in the example scenario. It recorded data from the Supervisory control and data acquisition (SCADA) systems controlling the equipment during its incubation period. It then starts actively attacking the facility by sending malicious parameters to make the equipment fail. It replayed the previously recorded data during the attacks to trick the operators from knowing the actual status of the equipment [20]. It appeared to the operators as just equipment malfunction. In this case, a slight change in the rotation speed of certain parts of the equipment caused them to malfunction and explode. STUXNET is considered to be an attack on a nation. If a nation is at risk from such attacks, it only makes it more apparent that a manufacturing company is even more susceptible to such attacks.

An attack such as STUXNET on the manufacturing industry may be a targeted attack against a company's sustainability. An attacker will launch attacks to disrupt operations until the company is forced to stop operations due to substantial financial losses. If the attacker cannot see the data being transmitted through the communication messages, it can help protect against the attacker’s reconnaissance attempts and stall following attacks. Unsolicited messages from attackers with possibly malicious instructions can be blocked if the data is checked for authenticity.

Hence, data confidentiality and authenticity have a significant impact on the industry's ecosystem. The SECS/GEM protocol is at the heart of the semiconductor industry, and therefore these issues are of serious nature. With the leap of the manufacturing industry into Industry 4.0, machines will need to communicate with other machines through the production network. With the ongoing Corona Virus Disease 2019 (COVID-19) global pandemic, during the time of this research, the need for remote access and communication with production machines has become more necessary due to work-from-home scenarios [21]. Managers and operators overlooking factory equipment require remote access to check equipment status all the time. However, allowing machines to connect to the network and operations personnel further increases the attack surface for cybercriminals to gain access to the production environment. Therefore SECS/GEM protocol's method of communication with binary encoded data becomes a major security issue and must be addressed to thwart attack attempts from cybercriminals.

All major industries are attempting to bring their factories up to the Industry 4.0 standards to reap the benefits. Machine-to-Machine communication is essential to automate the processes in every industry. For example, machines can communicate with other machines when they need more components, a change of recipe, or when an error occurs, the previous machine on the production line needs to stop sending more batches to process. Such coordination between factory equipment can help a lot with automation and with the overall efficiency of the manufacturing process as Industry 4.0 compatible factories would need lesser human interaction.

IV. Proposed Mechanism

This section describes, in detail, the proposed mechanism for preserving data confidentiality and authenticity in SECS/GEM during transmission in production networks. Data confidentiality is a critical part of the production network since data may go through several hops. This can be ensured using a secure encryption mechanism. This is necessary due to the wide range of devices, services, and networks that communicate/operate with a lot of data and thus present sufficient opportunity for data confidentiality violations as well as modifications due to the ease with which data may be accessed in SECS/GEM communication [22]. A data transfer mechanism for secure and efficient SECS/GEM communication is proposed in response to this requirement. The proposed mechanism is designed for the HSMS protocol in the SECS/GEM protocol stack. HSMS was chosen as it is the latest SECS/GEM protocol and is supplied with the latest machines.

We propose to use the Advanced Encryption Standard Galois/Counter Mode (AES-GCM) encryption scheme to achieve data confidentiality in SECS/GEM communication. Galois/Counter Mode (GCM) is one of several modes available for symmetric-key cryptographic block ciphers. It is adopted widely for its performance and throughput rates. With inexpensive hardware resources, throughput rates as high as 10 Gbps can be achieved [23]. It is an authenticated encryption algorithm that provides both data confidentiality and authenticity. GCM is defined for block ciphers that operate on a block size of 128 bits, and hence AES-GCM is used.

A. *Proposed Mechanism Design*

The proposed mechanism is designed to encrypt the data payload of the HSMS packet and verify its authenticity at the receiver end. The proposed mechanism's packet structure is depicted in Fig. 3. The message has 4 bytes of message length denoting the size of the HSMS message, including the header and payload length. The header of the message consists of 10 bytes. The header fields are described in Table II.

The header and the length bytes follow the same structure as in the standard HSMS message. The message payload, however, has a different structure from a standard HSMS message data payload. The data message payload of the proposed mechanism has a structure, as depicted in Fig. 3. It has fixed sizes for certain data at the beginning and end of the payload structure. The first 16 bytes of the message payload is the nonce. Next comes the ciphertext data message of variable length up to maximum payload size in bytes minus sum of nonce size and tag size. The last 16 bytes of the message payload is the message tag.

The nonce is a pseudorandom value of length 16 bytes. It is generated by the encryption mechanism as an input for internal use. The nonce is similar to an initialization vector (IV) used in various encryption schemes. The same nonce is required to decipher the ciphertext back into plaintext.

The tag is a hash of length 16 bytes generated by the encryption mechanism. It is used to verify the message's authenticity. The tag is computed during the deciphering process and checked with the sender's tag to verify message authenticity.

B. Proposed Mechanism Flow

Fig. 4 illustrates the flow of the proposed mechanism. Three inputs are required for the encryption mechanism to work, the pre-shared key, a nonce, and the plaintext data. The pre-shared key is a 256-bit symmetric encryption key (32 bytes). The nonce is a pseudorandom value of size 128 bits (16 bytes). It is used as an IV for the encryption scheme and the hashing function used to generate the message verification tag. The plaintext data is the HSMS message's original payload. The encryption scheme is AES-GCM 256, as the key is 256 bits in length, and a longer key implies increased security against exhaustive brute force attacks [24].

The algorithm used to encrypt the payload and generate the tag is shown in Fig. 5. The plaintext data is passed into the encryption mechanism along with the pre-shared key. A pseudorandom nonce is generated on the fly and is used as an initialization vector for the encryption mechanism's internal counter. The same nonce is required at the receiver end to decipher the ciphertext and is written to the data payload as it is safe to share nonce along with the message. The nonce is written to the first 16 bytes of the message payload. The encryption scheme then encrypts the data as 128-bit blocks using the provided key and part of the nonce as an IV for its internal counter. The ciphertext data is then appended to the message payload after the nonce. Upon completing the encryption process, a tag is generated by the encryption mechanism and written to the last 16 bytes of the message payload. This tag is essentially a hash generated by the encryption mechanism. The tag is used to verify the message authenticity on the receiver's end.

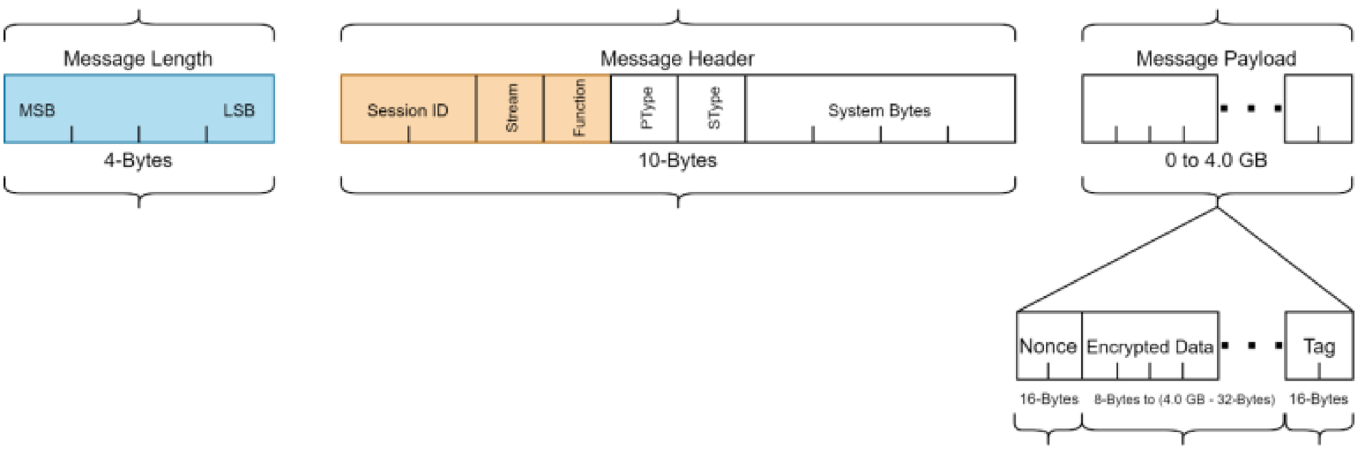

Fig. 3. Proposed HSMS Message Structure with Encrypted Data.

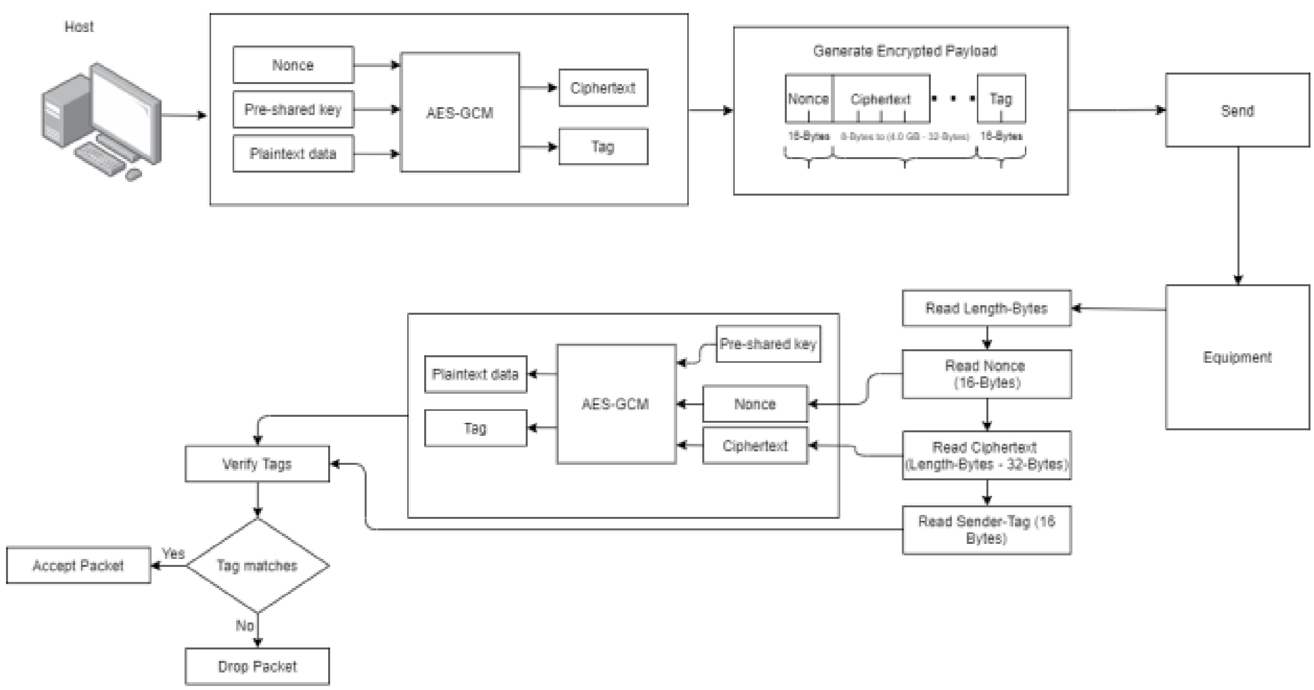

Fig. 4. Proposed Mechanism.

The algorithm used to decrypt the payload and verify its authenticity is shown in Fig. 6. On the receiver end, the data payload of the HSMS message is read as in the packet structure for the proposed mechanism. The first 16 bytes of the message payload are read as the nonce. Since the last 16 bytes of the encrypted payload is the tag generated by AES GCM, 16 bytes are subtracted from the length of the remaining payload, and the data is read for that length. Equation (1) can be used to calculate the size of the ciphertext data within the payload:

$$C_{len} = P_{len} - N_{len} + T_{len} \tag{1}$$

C_{len} is the ciphertext length computed by calculating the difference between P_{len}, the payload length, and the sum of N_{len} and T_{len}, where N_{len} is the size of nonce and T_{len} is the size of the tag. The nonce, ciphertext, and the pre-shared key are passed in as inputs to the decryption mechanism. The decryption mechanism takes 128-bit blocks of cyphertext and decrypts them. After decryption, a tag is generated by the decryption mechanism. This tag would be the same as the tag obtained from the encryption mechanism. If the tags match, the message is accepted; otherwise, the payload's authenticity fails, and the message is rejected.

	Algorithm: Send HSMS message with encrypted data
1	Start
2	***If*** the message length is 10, ***then*** Go to step 7
3	*nonce* = generate random value.
4	*ciphertext* = encrypt the payload with *preshared-key*, *nonce* and get ciphertext output
5	*tag* = Get message authentication tag from AES-GCM output
6	Replace message payload with *nonce* + *ciphertext* + *tag*
7	Send message
9	End

Fig. 5. Algorithm to Encrypt Payload and Generate Tag.

	Algorithm: Receive HSMS message with encrypted data
1	Start
2	***If*** the message length is 10, ***then*** Go to step 9
3	*nonce* = read first 16 bytes of payload
4	*ciphertext* = read payload size – 32 bytes of data
5	*plaintext* = decrypt *ciphertext* with *preshared-key*, *nonce* and get plaintext output
6	*tag* = Get message authentication tag from AES-GCM output
7	*sender-tag* = read last 16 bytes of payload

8	***If*** *sender-tag* is the same as *tag*, ***then***
	Replace message payload with *plaintext*
	Else
	Drop the message and go to step 10

9	Accept and process the message
10	End

Fig. 6. Algorithm to Decrypt the Payload and Verify the Authenticity.

The proposed secure version of the HSMS protocol runs on a different port from the standard HSMS protocol. For example, if the standard version runs on port 5000, the proposed version can run on port 5001. The secure version is thus distinguishable from standard communication protocol. A different port is required because the standard protocol would not be expecting an encrypted payload and may run into errors when trying to parse the payload. The proposed mechanism acts as an overlay protocol. It handles data confidentiality and authenticity on both ends and then forwards the message to the next layer, where the message is processed.

V. Implementation and Testbed Setup

A. Implementation

We used secsgem from [25], a python implementation of SECS/GEM protocols, as the base for our implementation. The implementation is free and available online on GitHub. For implementing AES-GCM encryption over secsgem, we used the Python Pycryptodome library from [26]. Pycryptodome is a library of implementation for cryptographic algorithms.

B. Experimental Testbed Setup

Our testbed consists of two machines running SECS/GEM simulator with Machine-I acting as the host and Machine-II as the equipment. Both machines have the configuration as stated in Table III.

TABLE III. Experimental Testbed Machine Configuration

	Specification
Processor	Intel Core i3-9100F @ 4.2Ghz
Memory (RAM)	2 GB
Operating System	Ubuntu 18.04 LTS
Network	100Mbps ethernet

Machine-I (host) was set up to be the active device initiating connections to machine-II. Machine-II (equipment) was set up to be a passive device listening for connections from Machine-I.

VI. Performance Evaluation and Results

For the evaluation of the proposed mechanism, the host machine was configured to connect to the equipment machine and send over 1000 SECS/GEM messages at regular intervals. The SECS/GEM implementation was configured to compute the time taken for processing while sending and receiving messages and store it in a log file. The experiments were conducted for both the standard HSMS protocol and the proposed mechanism. The processing times were then obtained from the log files for each experiment. The processing time obtained from the log files was labeled as described in Table IV.

TABLE IV. Processing Time: Label Description

Label	***Description***
Host-S	the processing time taken by the host to process the initial message to be sent (to equipment).
Equip-R	the processing time taken by the equipment to process the message received (from the host).
Equip-S	the processing time taken for the equipment to process the reply to be sent (to the host).
Host-R	the processing time taken by the host to process the reply received (from equipment).

C. Processing Time

The evaluation of the performance of the standard HSMS protocol and the proposed mechanism experiments and obtained the following results.

The standard HSMS protocol experiment's results are plotted in Fig. 7. It can observed that the host takes the longest time to send a message (Host-S), followed by the reply being sent from the Equipment (Equip-S). This variation is due to the differences in the size of the data payload. Host-S is the initial message, and Equip-S is the reply, essentially two different messages. The time taken for the host to process the response from the equipment (Host-R) takes the least amount of time, whereas processing time for the equipment to receive data (Equip-R) is slightly higher. This shows that the pattern in Host-S and Equip-S is the same in Equip-R and Host-R due to varying payload sizes of the initial message and reply message.

The processing times taken for the proposed mechanism are plotted in Fig. 8. The graph shows that the processing time for the host to send data (Host-S) was the longest. Following Host-S, the second-longest was the time processing time taken for the equipment to send a reply (Equip-S). The time taken for the equipment to process the message from the host (Equip-R) and the time taken for the host to process the reply from the equipment (Host-R) were similar. However, the processing time Equip-S was below the processing time Host-R for the most part. The pattern in the standard HSMS experiments is also seen in this experiment, meaning very well that the different sizes in the initial messages and the replies influence the processing time.

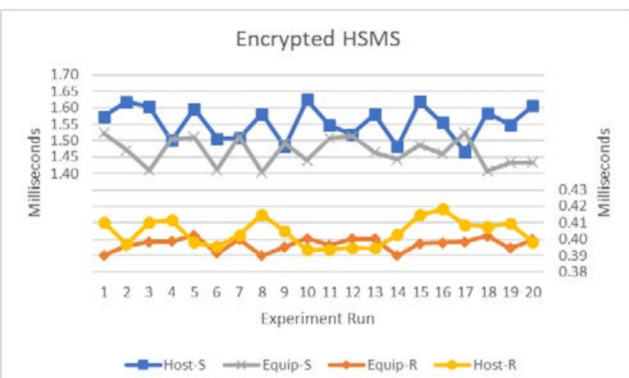

Fig. 7. HSMS with Data Encryption.

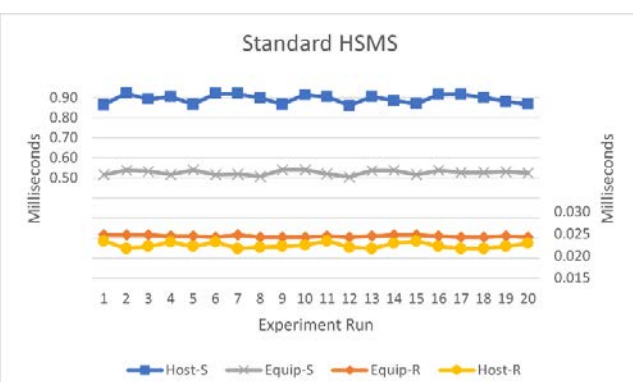

Fig. 8. Standard HSMS Experiment.

We computed the minimum, maximum, mean, and standard deviation in processing time for both the standard protocol and the proposed mechanism from the data we obtained in our experiments. Table V shows the mentioned metrics for the processing times of the standard protocol. It is seen that the mean processing time for Host-S and Equip-S is between half millisecond and one millisecond and Equip-R, and Host-R is below 1 microsecond.

TABLE V. PROCESSING TIME (MILLISECONDS): STANDARD HSMS

	Host-S	*Equip-R*	*Equip-S*	*Host-R*
Min	0.8607	0.0243	0.5054	0.0217
Max	0.9217	0.0248	0.5400	0.0234
Mean	0.8941	0.0245	0.5260	0.0224
SD	0.0218	0.0002	0.0112	0.0006

Table VI shows the metrics calculated for the processing time taken by the proposed mechanism. The results show that the mean processing time for Host-S and Equip-S is between 1.6 milliseconds and 1.4 milliseconds, and approximately 0.4 milliseconds for Equip-R and Host-R.

TABLE VI. PROCESSING TIME (MILLISECONDS): PROPOSED MECHANISM

	Host-S	*Equip-R*	*Equip-S*	*Host-R*
Min	1.464	0.390	1.404	0.394
Max	1.625	0.402	1.525	0.418
Mean	1.555	0.397	1.468	0.404
SD	0.051	0.004	0.043	0.008

Table VII shows the difference in processing times between the standard HSMS protocol and the proposed mechanism. The differences show that Host-S and Equip-S are between a half millisecond to one millisecond. Equip-R and Host-R are below a half millisecond. Analysis shows that encrypted SECS/GEM messages have a slight overhead. The time required for processing each message (sending and receiving) is increased by an average of 0.8 milliseconds due to encryption and decryption of data bytes in the HSMS message. The Encrypted HSMS message also has 32-Bytes of overhead. The nonce and tag are attached to the data bytes for the receiver to decrypt the ciphertext data. Thus, the maximum payload size is slightly reduced by 32 bytes as the proposed mechanism uses 32 bytes for the nonce and tag.

TABLE VII. PROCESSING TIME (MILLISECONDS): DIFFERENCE

	Host-S	*Equip-R*	*Equip-S*	*Host-R*
Min	0.603	0.365	0.899	0.372
Max	0.703	0.378	0.985	0.395
Mean	0.661	0.372	0.942	0.382

However, no encryption is performed for control messages such as "Link-Test Messages" as these messages do not contain any data bytes. The proposed mechanism checks for the length of data bytes and only performs encryption and decryption if the size of data bytes is greater than zero.

D. Control Overhead

Table VIII shows the control overhead for the proposed mechanism for messages with various payload sizes. For control messages without data, there is no added overhead. For a message of size 1 KB, we see an overhead of a 3% increase in payload size over the standard protocol. This is as a result of the nonce and tag being added to the payload. However, with bigger messages such as 1 MB and 10MB, we see the overhead is reduced drastically to a point where it is negligible as the size of the nonce and tag have fixed size for all messages.

TABLE VIII. CONTROL OVERHEAD

	Message Size (bytes)	*Control data (bytes)*	*Total*	*Control Overhead*
Control msg (header-only)	10	-	10	0.00%
Data msg (1KB)	1024	32	1056	3.03%
Data msg (1MB)	1048576	32	1048608	0.0031%
Data msg (10MB)	10485760	32	10485792	0.0003%

The processing time overhead observed is also negligible, considering that data confidentiality and authenticity are achieved in SECS/GEM communication. Furthermore, AES-GCM is a block cipher algorithm widely adopted for its performance. The experiments were conducted were on a general-purpose computer where the encryption was software-based. In a real industry scenario, this would be done on a dedicated yet inexpensive hardware-based encryption module, leading to even better performance of up to 10Gbps speeds of encryption.

E. Security Analysis of Brute-Force Attack

The proposed mechanism encrypts the plaintext data into ciphertext, making it meaningless to anyone monitoring the ciphertext data. Thus, passive attacks such as eavesdropping and reconnaissance are rendered useless as attackers will not be able to get the plaintext data. For an attacker to obtain plaintext data, the secret key is required for decryption. Without the key, the attackers can only try to make an exhaustive brute force attack to guess the key. The proposed mechanism uses a 256-bit pseudorandom key, and thus it would require the attacker to try at least half of the keys on average to find the correct one. Therefore, on average, the attacker will need to try 2^{255} different keys.

The latest processor with special instructions for AES operations uses about 0.16 cycles to process 1 byte of plaintext [27]. Table IX shows the time taken in years to crack the encryption with an exhaustive brute force attack. Equation (2) was used to compute the time required (in years) to break AES-GCM for various computers [28]. The results are shown in Table IX. T is the time complexity to break AES-GCM. $K_{possibilities}$ is the average number of keys the attacker has to try before finding the correct key. For the proposed mechanism, it is 2^{255} possibilities, as discussed previously. C_{sec} is the number of cycles or operations the CPU can perform in a second. C_{byte} is the number of cycles required to process one byte of plaintext, while B_{size} is the size of one block of plaintext in bytes. B_{size}, in this case, is 128 bits (16 bytes) as AES-GCM operates on 128-bit blocks. Y_{sec} is the total number of seconds in a year (60 × 60 × 24 × 365.25 = 31,557,600 seconds).

$$\mathrm{T} = \frac{K_{possiblities}}{\left({C_{sec}}/{C_{byte} \times B_{size}}\right) \times Y_{sec}} \quad (2)$$

TABLE IX. YEARS REQUIRED TO BREAK AES-GCM WITH 256-BIT KEY

Computer	*Speed*	*Time required in years*
Intel Core i7-10870H	280 Gflop/s	1.6773622363071781004323484314 75e+58
Fugaku (Japanese supercomputer)	442 Pflop/s	1.0625824121402938192784107710701e+52
All computers in the world	200 Gflop/s × 2 billion	2.2932686824512200591848513711572e+55

For our security analysis of the proposed mechanism, we calculated the time complexity of cracking AES-256-GCM on the latest Intel Core i7 processor and Fugaku, the world's most powerful supercomputer at the time of this research [29] and all the computers in the world combined. The total number of computers in the world is around 2 billion [30]. The results presented in Table IX show the number of years required to successfully brute force the key is in multiples of trillions of trillions of years. Thus, an attacker cannot decipher the ciphertext with the technology available as of now. It remains safe to assume that the proposed mechanism would not be broken anytime soon.

Using AES-GCM, the proposed mechanism attains data confidentiality. It can prevent passive attacks such as eavesdropping and reconnaissance by attackers. The data is encrypted, and thus, attackers are unable to read the data. As the data authenticity is checked, the proposed mechanism protects against MITM attacks where attackers try injecting false data or modify the data. An attacker cannot modify the data as it is encrypted. Even if the attacker has altered parts of the encrypted data in the message payload, the authenticity of the data will fail as every message has a tag to verify message authenticity. Thus, the message's authenticity is verified.

VII. CONCLUSION AND FUTURE WORK

In this paper, we proposed a mechanism for SECS/GEM's HSMS Protocol to attain data confidentiality and check data authenticity in its data communication messages by encrypting the data payload using the AES-GCM encryption scheme. We also evaluated the performance of the proposed mechanism with the standard protocol. The results indicate that AES-GCM encryption of HSMS data messages has a slight overhead of 0.8 milliseconds and 0.37 milliseconds when sending and receiving a message, respectively, compared to the insecure standard HSMS protocol. However, this overhead is negligible considering that encrypting HSMS data messages makes the protocol secure from eavesdropping attackers seeing the data transferred in the messages while also checking the authenticity of messages. Thus, the proposed mechanism achieves data authenticity and confidentiality. This will be a step further towards Industry 4.0 for the HSMS protocol-enabled machines.

The proposed mechanism aimed to protect data confidentiality and check data authenticity. However, SECS/GEM protocol has other shortcomings that need to be addressed to secure it completely. The proposed mechanism only encrypts the data payload part of a message. The header is still visible to the network. Although it does not expose sensitive data such as parameters, settings, or confidential data, an entity on the network can still see the frequency of each type of message sent on the network. Furthermore, SECS/GEM is still vulnerable to attacks such as replay and Denial of Service (DoS) attacks. Future research to enhance SECS/GEM security may include investigations into the implications of these problems and potential remedies. Future studies may potentially look at problems such as authentication and privacy for SECS/GEM communications in Industry 4.0 ecosystem.

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Evaluating and Comparing the Usability of Privacy in WhatsApp, Twitter, and Snapchat

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***Abstract*—With the increased use of social networking platforms, especially with the inclusion of sensitive personal information, it has become important for those platforms to have adequate levels of security and privacy. This research aimed to evaluate the usability of privacy in the WhatsApp, Twitter, and Snapchat applications. The evaluation was conducted based on the structured analysis of privacy (STRAP) framework. Seven expert evaluators performed heuristic evaluations and applied the 11 STRAP heuristics to the privacy policy statements and settings provided in the WhatsApp, Twitter, and Snapchat applications. This study provides useful information for designers and developers of social media applications as well as users of the apps. In particular, the results indicate that Snapchat had the highest severity rating, followed by Twitter and WhatsApp. Moreover, the most notable severity rating for all the apps was regarding the ability to revoke consent, where all of the apps had a very high number of usability problems.**

***Keywords*—HCI; usability; heuristics evaluation; STRAP; privacy; usable privacy; social media**

I. Introduction

Individuals are becoming more reliant on social media platforms as essential mediums for communication. The global average penetration rate for social media increased from 40% in 2018 to 49% in 2020 [1]. In other words, more than three billion people use social media. Most social media users prefer to connect to their accounts using an application (app) on their smartphones [1], [2]. Social media platforms provide individuals with ways to interface and offer information and snapshots of their lives.

As the commitment of users to social networking platforms expands, the volume of private and personal data that is shared online increases in a like manner. While these platforms offer privacy settings so that users can secure their online privacy, several reports (as cited in [3]) have shown that the average social media user does not change his or her security settings. A lack of public knowledge has resulted in the intermittent use of these settings by many users. Albesher and Alhussain [4] discussed the reasons for not adjusting privacy settings, which included a lack of awareness of the possible risks, the time it takes to read and understand each setting, and the diversity of the settings.

This paper contributes to the knowledge of understanding the term “usable privacy” and how it can improve the usability of privacy settings and policies in social media. As a result, users would deal with these settings and policies effectively and efficiently. Comparing the privacy settings and policies of three different examples of the most popular social media grants practical ideas for improving the design of usable privacy settings and policies. This comparison becomes more useful when a trustable framework is applied. This paper evaluates the usability of privacy settings and policies in the WhatsApp, Twitter, and Snapchat apps within the structured analysis of privacy (STRAP) framework [5]. It further contributes to the existing knowledge on online privacy by testing the STRAP framework in the usability of privacy context. The study provides useful information for designers and developers of social media applications as well as users of the apps to enhance the usability of privacy. All the investigated apps could involve similar privacy issues, and it is a user’s responsibility to carefully adjust the privacy settings to protect his or her information. Although WhatsApp looks simple in terms of usage, it could present several privacy issues because it allows communication with unknown people. Users are responsible for deciding who can see their personal information, such as their profile photos and “about” sections. Conversely, while Twitter and Snapchat appear to be public networks, they allow users to keep their private information hidden from the public. A consequence of that policy is that users can control several aspects of privacy when selecting options for their privacy settings in those apps.

The paper is structured as follows. Section II introduces usability and privacy, followed by more details about the usability of privacy in social media. Next, Section III describes and justifies the research methodology used in this study, and the data collection methods used is presented. Section IV presents and discusses the main results, and Section V presents the conclusion.

II. Literature Review

A. Usability

Usability is a well-known concept in design. Recently, usability has become a popular term when designing privacy policies and settings. Generally, the usability of a system refers to the measure of certain metrics, such as the ease of use and efficiency of that system. Similarly, the usability of a private setting or policy means measuring the ease of reading, locating, and adjusting that setting [6]. A potentially appropriate definition of usability for all fields of study could be “an evaluation of the level of quality of a user’s experience (UX)” because UX has a broader meaning [6]. In fact, Don Norman indicated that UX covers different parts of the interaction between users and systems. This interaction includes industrial design graphics, interfaces, physical interactions, and manuals [7].

B. Privacy

Privacy has different definitions and they are varied depending on the entity that is protected. Nonetheless, privacy has general definitions that could be broad enough to cover many privacy issues. One example is the definition by Oxford English Dictionary (as cited in [8]) which defined privacy as the "state or condition of being free from being observed or disturbed by other people". Another example was brought by Warren & Brandeis [9] which is "the right to be left alone". On the other hand, there are specific definitions for specific entities such as information privacy. According to Miltgen and Smith [10], information privacy concerns the security of personal or private data and, as a rule, identifies individual information stored on PC frameworks. For the most part, Miltgen and Smith [10] insisted that information privacy is viewed as a significant part of data and information sharing. This position is based on, for example, the view that, given the headway made in the digital age, personal and private data vulnerabilities have expanded. Similarly, Choi, Park, and Jung [11] stated that information privacy is already applicable in many forms that aim to secure personal user data. These researchers further indicated that information privacy might be applied through various means, including encryption, data and information masking, or authentication—each to guarantee that data are accessible to only those with approved access. These defensive measures are designed to forestall information mining and the unapproved utilization of individuals' data.

More particular, there are some specific definitions for privacy that can be very useful for the case of protecting personal information in social media. For instance, Bünnig and Cap [12] defined privacy as "protecting personal information from being misused by malicious entities and allowing certain authorized entities to access that personal information by making it visible to them" (as cited in [13]). Additionally, Alan Westin [9] described privacy as the right to let people decide when, how, and to what extent their information is exposed to others (as cited in [14]).

C. Privacy Settings

When people register for social media, they are presented with certain privacy policies and settings; in this context, privacy settings refer to the restriction of the disclosure of shared content to only authorized people [3]. Users could be considered the authors of the settings, but then different usability problems could occur [15]. Indeed, more usable privacy settings lead to experiences that better meet users' preferences and needs [16]. Akcora and Ferrari [17] posited that users will make poor decisions about their private information when they must deal with many options in privacy settings.

Kane [18] observed that social networking platforms offer people simple approaches to interacting online, making new companions, and staying in contact with existing connections. Nonetheless, Kane [18] asserted that in meeting individuals on the internet with whom one has no prior acquaintance, a user encounters certain inherent risks. Kane [18] insisted that users, when talking and sharing ideas and information online, should remember that once a message, photograph, or video is shared, they no longer have any influence over where it goes. Trottier [19] asserted that the need for privacy settings emerged because of that feature. Privacy settings are control mechanisms accessible on social networking platforms and sites that permit clients to limit who can see their profiles and filter what data or information other users or guests can see. Put simply, privacy settings help guarantee that online users have control over the friends they choose to accept online and whether the information they share is made public or not.

D. Usability of Privacy

The usability of privacy is not a new concept although scholars used slightly different terms to refer to this concept. For example, Aldhafferi et al. [13] mentioned the term "privacy by design" and defined it as granting more authority to users to specify what type of information they want to share and with whom. Another term that has a similar meaning is "usable security," which refers to whether an app grants its users enough information to make informed decisions about who can access their data and with whom it is shared (as cited in [20]).

Over the last decades, use of the term "usable privacy" has increased rapidly because there has been a significant increase in the number of research papers studying this term [21]. In fact, there are well-known conferences such as the Symposium On Usable Privacy and Security (SOUPS) that are conducted to encourage researchers to publish in this area. Additionally, there are specific courses in highly ranked universities such as Carnegie Mellon University and the University of California-Berkeley that are named "usable privacy and security".

Some scholars have defined usable privacy as the ability of users to locate, understand, and successfully use privacy controls to protect their privacy [22]. Thus, developers should design interfaces that help users protect their privacy through alignment with this concept. By applying the fundamentals of user-centered design to privacy, organizations can enhance their users' trust and avoid legal issues [22].

There are several research papers and projects related to usable privacy. For instance, Raschke et al. [23] relied on usability engineering lifecycles that were created by Nielsen and Möller to evaluate privacy. They aimed to design a usable privacy dashboard that could manage the requirements of the General Data Protection Regulation (GDPR). Additionally, Sadeh et al. [24] aimed to achieve usable privacy policies by combining crowdsourcing, machine learning, and natural language. In this project, they relied on the principles of iterative, user-centered design. Moreover, Angulo et al. [25] proposed an approach for designing usable interfaces for privacy policies to assist users in making mindful decisions regarding the dispersal of their personal information. This approach relied on predefined levels of privacy settings. Furthermore, Jones et al. [26] designed a prototype for privacy policies for a British media service. This prototype created a new interactive design that helped users make informed decisions about their data usage. The results showed that users were more comfortable with the new design, which had positive effects on their trust in the media service.

E. *Usability of Privacy Settings in Social Media*

Privacy settings are a central issue for users of social media. Fiesler et al. [27] indicated that the principal choice users must be aware of when they are creating accounts on Twitter is whether they will post secure tweets or open tweets. The secured tweet highlight implies that nobody other than a user's permitted followers will see the user's messages. It also means that other users will not be able to retweet the user's messages or post them to their streams. If a user picks a secured account, the user can also generally change it later to an open account in the privacy settings. However, it should be noted that Twitter fails to offer the same degree of granular control as other social media platforms. Regardless, it has some better-than-average choices for controlling what different clients can see and what level of access they need to interact with another user. These settings are more for controlling tweets that are sensitive, both the tweets a user creates and the tweets a user views. Accordingly, Twitter permits clients to not only block delicate media but also mark something they are going to post as sensitive. For instance, the privacy setting "Safety" is the place where users can choose to reject tweets that are offensive or unwanted, as well as mute or block accounts. Likewise, there are privacy settings that allow users to select, for instance, a setting to "receive anybody" or the option to allow read receipts.

Dev, Das, and Camp [28] indicated that WhatsApp settled on a security decision dependent on usability because it had 1 billion clients and closing down conversations could be irritating for many clients. This means that the entire framework may be less secure. However, although most clients know that they can modify their WhatsApp privacy settings, the majority only use the privacy options "everybody" or "my contacts," conceivably on the grounds that they want to permit family and friends to see whatever they post online. While there are other options in the privacy settings for WhatsApp, most WhatsApp's clients use only the basic settings, indicating that the use of the privacy settings is not that common for users.

Furthermore, WhatsApp offers its users the ability to control who can access their online data. Regardless of whether users decide to limit access to their data, they are given the option to choose a specific setting, for example, to display their online data either to their entire contact list or to no one else under any circumstances. Dev, Das, and Camp [28] appeared to insist that a user can change who has permission to view the user's profile photograph, "about" message, and status in the privacy settings, with differing results for the various choices. For instance, if a user hides the "Last Seen" setting, it means that the user's contacts will not see when the user last logged into WhatsApp. Conversely, even if a user does not use this degree of protection, he or she should be aware that others might.

In contrast, Snapchat is tremendously well known for its privacy settings, as Mondal et al. [29] articulated. Snapchat's prevalence implies that if users are not cautious, they will undoubtedly receive snaps, invites, spam, or even calls from random individuals—unless they secure their privacy on Snapchat. There are a few settings for enabling or disabling Snapchat features that will successfully forestall all the issues mentioned above. Mondal et al. [29] mentioned that Snapchat offers a variety of privacy settings that users are expected to alter to fit their inclinations and comfort level. For the most part, these settings are overtly simple to locate and can be turned on or off whenever users wish, should their perspective on any one aspect later change. In addition to its settings, Snapchat provides general protection updates that users have access to, such as notices about how to use Snapchat without unintentionally sending a private Snapchat to the wrong individual or posting something to their story that they initially intended to send privately. The usability of the privacy settings in Snapchat is moderately high given the ease of use.

Aljohani et al. [30] also mentioned the privacy settings in Snapchat, which, like an instant messenger, permits users to send photographs and drawings regardless of content. Pictures posted in a straightforward manner to companions vanish from Snapchat's servers after the assigned 24-hour timeframe lapses. In contrast to other networking platforms, Snapchat clients must add companions to have the option to collaborate, which demonstrates the usability of its privacy settings. If somebody unknown to a user attempts to send a snap, the user will be informed that he or she needs to include the sender as a companion. As already noted, users can modify Snapchat's privacy settings for enhanced security. The settings to adjust include the option of who can send snaps and who can see an account. Users can also select either "everybody" or "my friends only" for who will have access to the snaps they post. However, several privacy risks are associated with the use of such social media networks, which is the topic of the next section.

F. *Privacy Risks in Social Media*

Townsend and Wallace [31] reported that online users frequently post statuses about being out of town, visiting new locations, leaving their apartments with no one at home, and much more such information. Moreover, online users post photographs of themselves and share their complete names and birthdays, where they went to school, and where they work, all while seemingly unaware of the possibility that somebody could use that information to attempt to hurt them, find them, or impersonate them. A New York Times analytical report uncovered that an American organization named Devumi gathered millions of dollars in a shady worldwide commercial online fraud scheme. The company sold Twitter followers and retweets to individuals who hoped to become influencers on social media and increase their online popularity [32]. Devumi's customers were provided with millions of followers with profiles that could have been profiles of anyone but were certainly not profiles of actual people. This illustrates one of social media's privacy risks.

While there is proof that social networking platforms have been significant to individuals, Bergström [33] indicated that individuals are hesitant regarding issues concerning the personal data that are gathered and shared and the security of their information. For example, a 2014 review found that 91% of Americans concurred or unequivocally agreed that they had lost authority over how their private and personal data are gathered and used by a wide range of actors. In addition, a significant number of social media clients reported that they worried about businesses and organizations gaining access to the information they share on networking platforms. Based on these concerns, most online users supported the recommendation that governments be more involved in regulating promoters.

Baruh, Secinti, and Cemalcilar [34] noted that other surveys have revealed that social media platform users are not confident concerning their privacy settings in services such as Twitter, Snapchat, and WhatsApp. This is because most users are convinced that social media organizations are not capable of securing the information they share online. Even worse, Bergström [33] stated that users' concerns regarding privacy settings are founded on the fact that most users struggle to comprehend the nature and extent of the information gathered about them. Only a few social media users believe they have significant control over the data collected about them, which is certainly not always the case.

III. Methodology

A review of the available research methods for an evaluation study of the usability of privacy guided our decision to adopt the STRAP framework. Heuristic evaluation is a technique that is dependent on specific principles or rules ordinarily referred to as heuristics. Essentially, when performing a heuristic evaluation, a specialist evaluator uses guidelines for checking a compliance list to not only assess usability but also assign severity ratings to the heuristics [35]. Accordingly, in this type of evaluation, the heuristics incorporate a mixed combination of components, the greater part of which are derived from Nielsen's heuristics. This means that the principles and rules observed in heuristic evaluations can be derived either from explicit guidelines, practices, or hypotheses. In this way, proper heuristics offer designers the most effective corrective measures.

There are several advantages to this method that demonstrate why it is the most frequently chosen technique for usability analyses. More specifically, heuristic evaluations are not only fast but also intuitive, which allows them to provide feedback outcomes more quickly. In addition, they are moderately economical because time is conserved and assets are managed effectively [35]. Heuristic evaluations can also be joined with other ease-of-use testing strategies to more closely inspect potential ease-of-use issues. Using such a methodology prior to evaluator testing can reveal the quantity and seriousness of the design and development mistakes found by experts.

STRAP heuristics is a framework that is centered on user design and acts as a privacy awareness design tool. The objective of the STRAP framework is to address a portion of the investigations performed on privacy analysis systems. Accordingly, the STRAP framework joins components of heuristic evaluation and goal-focused analysis with an end goal of accomplishing viability while minimizing expenses [5]. A basic property of the STRAP framework is that it is not necessary for analysts to learn new skills or abilities. It is basically meant to support analysts by distinguishing privacy issues and the usability of systems. In turn, it is an add-on technique and is not used for addressing other components of design procedures. Table I shows the details of the STRAP heuristics.

TABLE I. STRAP Heuristics and Descriptions for Each

Heuristic		Description
1-Notice/Awareness	a. Available, accessible, and clear	Information about app activities is always available to users in a way that is simple to access and understand.
	b. Correct, complete, and consistent	Disclosure is complete, correct, and consistent in order for users to make informed decisions.
	c. Presented in context	Relevant information is presented for each transaction to minimize memory load and ensure users are aware of the consequence of their actions.
	d. Not overburdening	Disclosure takes into consideration human limitations in memory, ability, and interest. It provides succinct and relevant information.
2-Choice/Consent	a. Meaningful options	Whenever possible, users are given real options rather than opt-in/opt-out choices to avoid coercion and maximize benefits.
	b. Appropriate defaults	Privacy default settings reflect most users' concerns and expectations with regard to protecting their privacy.
	c. Explicit consent	The app avoids assuming consent whenever possible.
3-Integrity/Security	a. Awareness of security mechanisms	Users are provided with enough information to judge the security of the app and their information.
	b. Transparency of transactions	The app provides transparency in transactions and data use to build user confidence and trust.
4-Enforcement/ Redress	a. Access to own records	Users have access to all information the app has collected about them, regardless of source.
	b. Ability to revoke consent	Consent is retractable.

A. Justification for using the STRAP Framework

For investigating the usability of privacy in terms of HCI issues, relevant privacy frameworks are reviewed and can be broadly divided into two classifications:

1) Guidelines: The Fair Information Practices are a prime example of guidelines; they were early design guidelines designed to support data protection regulations and provide a system-centered viewpoint.

2) Process frameworks: Examples of process frameworks include the STRAP framework [35] and the question options criteria (QOC) process. These offer direction in terms of the evaluation and design of privacy-sensitive IT applications and have a user-centric emphasis.

The structured analysis of privacy (STRAP) framework puts forward 11 dedicated sets of privacy heuristics that are intended to be employed by designers to assess interactive systems. Based on usability heuristics and fair information procedures, the STRAP framework represents a structured method of evaluating nonfunctional user requirements (NFRs). There are two primary motivations as to why the STRAP heuristics are useful for this study. First, the approach is based on the notion that designers do not have a strong track record of paying sufficient attention to addressing social issues, such as privacy, when designing information systems. As such, they benefit from the utilization of a simple, lightweight application that can highlight social problems such as privacy. Second, heuristic evaluation approaches are affordable and valuable.

Additionally, the effectiveness and efficiency of the STRAP heuristics have been tested and evaluated by several researchers, such as Jamal and Cole [36] and Jensen [37], who have found that the tool represents a useful means of identifying security, privacy, and correlated usability problems. The explanation for picking the STRAP usability heuristics as opposed to others is that the STRAP heuristics indicate the weakness identified in privacy issues [5]. Jensen and Potts [35] stated that nonfunctional requirements are those related to the quality of a system. In that regard, the STRAP framework combines heuristics from other relevant frameworks, such as “GBRAM,” which makes it more effective as it builds on goal-oriented analytical approaches [38]. Gritzalis et al. [39] asserted that the STRAP framework proves to be more than effective when evaluating the privacy of systems. Regarding social media apps, the STRAP framework can be used to evaluate privacy based on whether they provide effective protection from privacy vulnerabilities. For instance, Gritzalis et al. [39] mentioned that the STRAP framework is effective because it combines elements of heuristic evaluation and elements of goal-oriented analysis, which not only minimizes expenses but also achieves better effectiveness. Moreover, for evaluating social media app privacy, the STRAP framework is justifiable because there is no need for analysts or evaluators to learn different or new skills. In these ways, the STRAP framework supports analysts in identifying privacy issues in social media apps.

B. Data Collection and Analysis

In this study, a STRAP heuristic evaluation was used to evaluate the usability of privacy for the WhatsApp, Twitter, and Snapchat apps. The reason for selecting three apps was to be able to make a reasonable comparison. In fact, the selection of these apps was based on their usage ranking and simplicity. For example, unlike Facebook, which has an unclear main purpose, Twitter is known for microblogging news, WhatsApp for instant messaging, and Snapchat for sharing personal stories.

Table II provides the specific versions of each app that were investigated. There were minor differences between the tested apps on Android and iOS. However, the authors ensured that these minor differences had no effect on the evaluation. In fact, some evaluators used Android, while the others used iOS.

TABLE II. THE INVESTIGATED VERSION OF EACH APP

App	Android	iOS
WhatsApp	2.20.157	2.20.51
Twitter	8.45.0-release.00	8.19
Snapchat	10.82.50	10.82.5.78

The authors of this study asked for the participation of eight faculty members in the departments of information technology and information systems in different universities near their area who had experience in this type of evaluation. The selection was based on the authors’ knowledge of who had the ability to perform this type of evaluation. One faculty member refused to perform the evaluation, claiming that there was no reward, while the others agreed. As stated by Nielson [5], heuristic analysis can be highly effective for general HCI problems by a small number of evaluators. In fact, Nielsen and Molich [40] recommended 3 to 5 evaluators to find most of the usability problems. However, we asked three more evaluators to ensure that we cover a larger number of usability problems.

Each evaluator performed the evaluation separately to avoid influencing each other. The evaluation process began with the expert evaluators applying the 11 STRAP heuristics (stated in Table I) to evaluate the privacy policy statements and settings provided by WhatsApp, Twitter, and Snapchat. All of the evaluators were given the same procedures to perform during the evaluation. For each privacy heuristic that was violated, the evaluator assigned one of the following severity ratings:

0 = I don’t agree that this is a usability problem at all

1 = Cosmetic problem only

2 = Minor usability problem

3 = Major usability problem

4 = Usability catastrophe

Seven expert evaluation lists were produced and then merged into one list by calculating the severity ratings for all of the survey statements for WhatsApp, Twitter, and Snapchat. For example, the number of evaluators for every severity rating for each heuristic for WhatsApp was counted, and then this number was multiplied by the severity rating to obtain the total (3); the totals are shown in Table III.

TABLE III. RESULTS OF THE STRAP HEURISTIC EVALUATIONS OF THE THREE APPS

Heuristic		WhatsApp	Twitter	Snapchat
1-Notice/Awareness	a. Available, accessible, and clear.	3	8	14
	b. Correct, complete, and consistent.	8	9	13
	c. Presented in context.	9	11	17
	d. Not overburdening.	8	6	10
2-Choice/Consent	a. Meaningful options.	12	14	18
	b. Appropriate defaults.	7	15	19
	c. Explicit consent.	17	10	14
3-Integrity/Security	a. Awareness of security mechanisms.	8	12	16
	b. Transparency of transactions.	11	11	16
4-Enforcement/ Redress	a. Access to own records.	19	9	10
	b. Ability to revoke consent.	17	17	20
Total		116	122	167

IV. RESULTS AND DISCUSSION

The severity ratings of the usability problems regarding privacy issues in each app are presented in Table III. This table includes both the ratings for each heuristic individually and the ratings for all heuristics added together. The description of each heuristic was previously provided in Table I. Table III reveals that, overall, Snapchat had the highest severity rating (167), which was much higher than the ratings for WhatsApp (116) and Twitter (122). It shows the total severity rating for each app based on the five scales of the severity rating. As shown in Table III, the severity rating for Snapchat exceeded the score for minor usability problems.

Snapchat consistently had the highest rating for each separate heuristic except for meaningful options and access to the user's own records, where WhatsApp had the highest ratings. In the rest of the heuristics, Twitter had higher usability problem ratings than WhatsApp, except in three heuristics. In the heuristic "not overburdening," WhatsApp had a higher rating (8) than Twitter (6). In the heuristics of "transparency of transactions" and "ability to revoke consent," the apps had the same ratings (11 and 17, respectively). In fact, when the five scales of the severity rating are applied to one heuristic individually, the maximum score is as follows:

Catastrophic = 28

Major = 21

Minor = 14

Cosmetic = 7

None = 0

By looking at the severity rating for each heuristic separately, WhatsApp had the lowest rating (3) with regard to the availability, accessibility, and clarity of privacy notices. Twitter's rating (8) was notably higher than WhatsApp's rating, while Snapchat's rating (14) was the highest. This result is not surprising given that Snapchat suffers from various issues that belong to this heuristic. Snapchat confuses users by mixing certain information together and making several settings difficult to understand. For example, Snapchat has a section called "additional services" that contains several privacy settings, and under that section, there is another section called "privacy," as shown in Fig. 1. Additionally, Snapchat takes users away from the settings screen when they do not interact with the app for a few moments, which makes it difficult for users to return to where they left off.

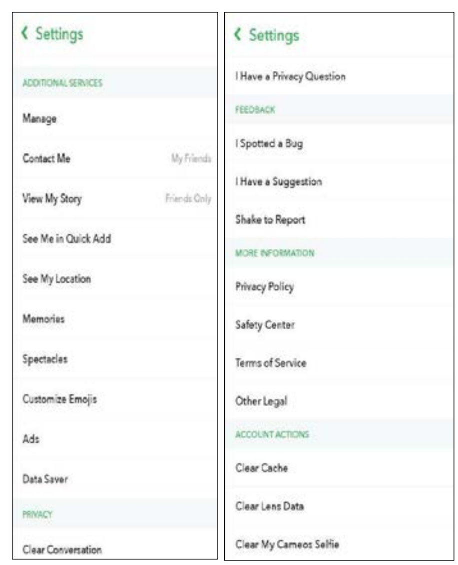

Fig. 1. Privacy Settings in Snapchat.

In contrast, WhatsApp has all its privacy settings in one location (i.e., under "privacy"). Furthermore, this section is displayed with a lock sign, which gives users a hint about the types of settings in that section. Moreover, this section is contained under "account," which is designated with a key symbol, as shown in Fig. 2. Additionally, the privacy policies are listed under "help," which is denoted by a question mark sign. Using icons reduces the mental load for users and allows for smooth navigation [41], [42]. Thus, the privacy settings and policies look organized and clear in WhatsApp. In Twitter, the privacy settings also look organized; however, it is not clear how to find the privacy policies. It is important to mention that the interface of the privacy settings may look slightly different in the two operating systems that were investigated (Android and iOS). However, the analysis is still valid for both. Regarding the second heuristic (Table III, 2a), which measures the completeness, correctness, and consistency of a disclosure, the severity rating was similar for WhatsApp (8) and Twitter (9) but was notably higher for Snapchat (13).

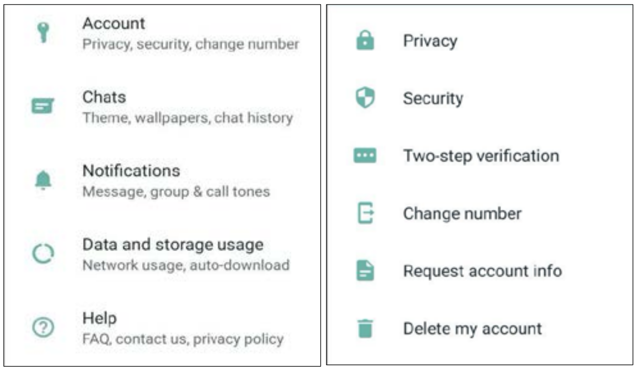

Fig. 2. Privacy Settings in WhatsApp.

The fourth heuristic (Table III, 4a), measuring whether a disclosure is overburdening, resulted in a slightly lower severity rating for Twitter (6) than for WhatsApp (8) or Snapchat (10). It is not surprising to see that Twitter's rating is the lowest here. One reason is that Twitter divides its privacy policies into sections, each of which is color coded, as shown in Fig. 3. The colors make it easy for humans to link information to the right section. In fact, some scholars have indicated that "color in user interface can control the user's attention, help to recognize interface elements, express the meaning of indicators in complex professional systems, as well as be used for visual grouping of similar objects" [43].

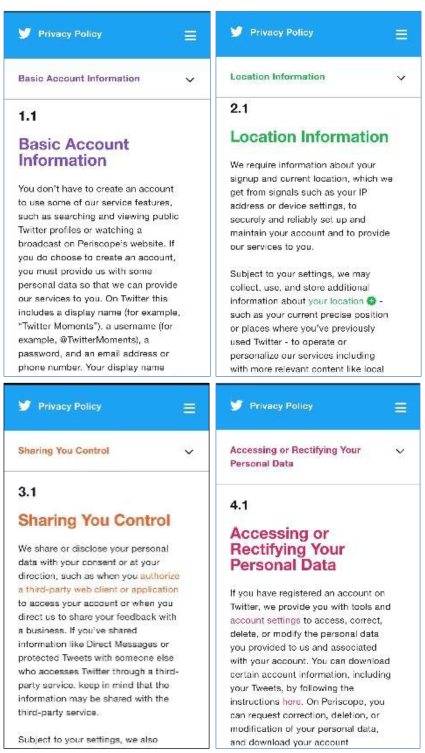

Fig. 3. Privacy policies on Twitter.

The third heuristic, which measures the presentation of relevant information that belongs to each transaction, revealed that the highest severity rating was given to Snapchat (17). Twitter's rating (11) for this heuristic was closer to that of WhatsApp (9). Generally, Twitter provides a short explanation for each setting and a link to "learn more," as shown in Fig. 4. Conversely, while neither Snapchat nor WhatsApp provides a link to additional explanations for each setting, WhatsApp performs slightly better because it does not have jargon that could result in some users being unaware of the consequences of certain actions. For instance, Snapchat has the setting "clear top locations," which is used for "Map Actionmoji." However, there is inadequate information provided about this jargon and the consequences of the setting.

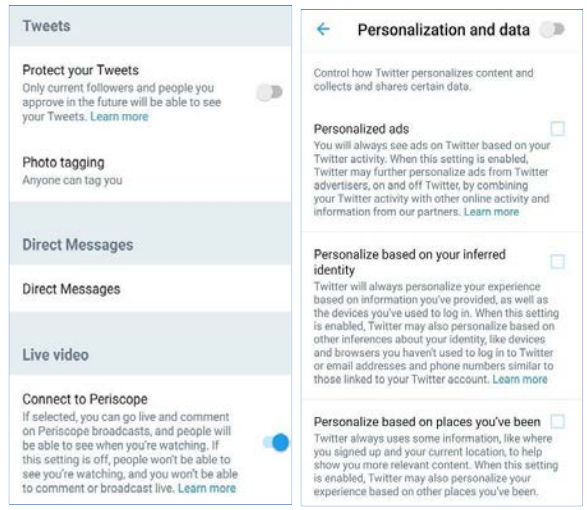

Fig. 4. Privacy Settings on Twitter.

Generally, the heuristics evaluating "choice and consent" revealed more usability problems than the heuristics evaluating "notice and awareness." In the second group of heuristics, evaluating whether apps provide meaningful options, all the apps had high severity ratings. Specifically, the rating was 12 for WhatsApp, 14 for Twitter, and 18 for Snapchat. In other words, users are given the choice to opt in or opt out rather than more specific options for most privacy issues. The next heuristic in this group, which evaluated whether the apps had appropriate defaults, resulted in a significant difference between WhatsApp and the other apps. WhatsApp's rating (7) was less than half the ratings for Twitter (15) and Snapchat (19). WhatsApp still does not allow banner ads as Twitter and Snapchat do, which is one reason for the lower rating for WhatsApp. Additionally, Twitter and Snapchat normally allow interaction with unknown people more than WhatsApp does.

Moreover, because Twitter and Snapchat sell ad space, they prefer that users select the default settings, which maximize their benefits. Snapchat has the highest score here because it is basically about sharing a personal story and, thus, it is about sharing very sensitive information. In marked contrast, WhatsApp's rating for avoiding an assumption of consent whenever possible was the highest (17) compared to Twitter (10) and Snapchat (14). An example that could explain why WhatsApp had the highest rating here is the fact that users have no choice about whether to share their private information with

Facebook. Overall, usability problems were high for all the apps under this heuristic. One reason for the usability problems is that the apps share users' private information with third parties whether the users agree or not.

The evaluation of the awareness of security mechanisms and transparency of transactions shows that Snapchat had the most usability problems overall. One reason for this evaluation is that Twitter and WhatsApp explain why they collect data in several cases, unlike Snapchat. WhatsApp and Twitter also provide specific explanations of the data they collect, while Snapchat provides general explanations to encompass all the data it collects. However, all the apps need to provide more convincing details about how users' data are being used and how users are protected. In Twitter, several settings cannot be controlled solely through a user's Twitter account. Users are therefore asked to opt out of other organizations' services to attain certain privacy goals. This is commonly seen with settings related to ads. For example, users are encouraged to opt out of Google Analytics by installing Google's opt-out browser add-on and to opt out of interest-based Google ads using Google's Ads Settings.

In the last group of heuristics, evaluating users' ability to access their own records, WhatsApp had the worst severity rating (19). In fact, WhatsApp does not provide a clear way for users to access their own records. Conversely, Twitter and Snapchat clearly show that feature in their privacy settings. Because not all records are accessible, usability issues still existed for this heuristic. The results related to the last heuristic, measuring the ability to revoke consent, are the most notable because all the apps had a dramatically higher number of usability problems. In other words, there is no option to revoke the user agreement in any of these apps. In Twitter, consent is revocable for several settings but only with certain conditions. In other words, changes may not occur immediately or may not be applied in certain cases. For example, when users change the setting for their tweets from public to protected, there is no guarantee that no past tweets will be shown in search engine results.

V. Recommendation

Based on the analytical results of the current study, we can say that the way privacy settings and privacy policies are presented needs to be reconsidered. The tested apps present their privacy settings and privacy policies differently, which makes using them difficult. For example, WhatsApp places its privacy policies under "Help", Twitter under "About Twitter", and Snapchat under "More Information". The current presentation or mapping works against one of the core principles of usability (i.e., consistency). Thus, it is recommended that these apps make privacy a main section that includes both their privacy settings and their privacy policies.

Another recommendation is about the need to attach interactive visual signs to the text that describes the privacy settings and policies. Furthermore, assigning different colors for different settings and policies helps users recognize the differences between them and increases their learnability toward the usage of the settings and policies.

VI. Conclusion

This paper presented a heuristic evaluation of the usability of privacy in WhatsApp, Twitter, and Snapchat based on the STRAP framework. It highlighted useful information for designers and developers of social media applications as well as users of the apps to enhance the usability of privacy. The results of the study pointed out several privacy issues in each of the investigated apps. It further indicated that Snapchat had many more usability problems than WhatsApp and Twitter, which had relatively close scores regarding usability problems. In terms of evaluating each heuristic individually, the most notable severity rating for all the apps was on the ability to revoke consent, where all the apps had a very high number of usability problems. Overall, careful consideration needs to be given to the issues discussed in this paper to enhance the usability of privacy in these social media apps. Finally, it is suggested that future research should consider how to increase users' awareness to protect their information on social media networks.

Acknowledgment

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Genetic Algorithm and Ensemble Learning Aided Text Classification using Support Vector Machines

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***Abstract*—Text classification is one of the areas where machine learning algorithms are used. The size of the dataset and the methods used for converting the textual words into vectors play a major role in classifying them. This paper proposes a heuristic based approach to classify the documents using Genetic Algorithm aided Support Vector Machines (SVM) and Ensemble Learning approach. The real valued representation of the textual data into vectors is done on applying Term Frequency – Inverse Document Frequency (TF-IDF) and Bi-Normal Separation (BNS). However, in this paper, the common data misclassification issue in SVM is overcome by introducing two algorithms that adds weightage to accurate classification. The first algorithm applied BNS and TF-IDF along with ensemble learning and constructs a voting classifier for classifying the textual documents. The results produced justify that TF-IDF produces good results with voting classifier than BNS for classification. Henceforth TF-IDF is applied in the subsequent approach for vector generation. Secondly, genetic algorithm is applied along with OneVsRest strategy in SVM to overcome the drawback of multiclass multilabel classification. The results show that Genetic algorithm improves the accuracy of classification even with a very small labelled dataset, as genetic algorithm applies the process of Mutation and Cross over across many generations to understand the pattern of right classification.**

***Keywords*—Genetic algorithm; ensemble learning; support vector machines; text classification**

I. Introduction

Text classification is a primary domain focused by companies that handle big data and big data related applications. To search the relevant and related documents, these companies evolve new methods to classify and organize their data. Extensive collection of research articles, newspapers, journals and other related textual content are available online to be classified in various categories. It still remains a cumbersome process to sort them with prevailing algorithms as they are time consuming and are inefficient. However, machine learning algorithms have a forte in these kinds of applications. There exist many supervised algorithms such as Naïve Bayes (Probabilistic Generative classifier), Decision Trees (DT), Random Forest (RF), SVM which are used for text classification. Though in earlier days SVM were not used for text classification, in earlier 2000s, it contended with neural networks producing the most desirable results [1]. SVM is compared with Logistic Regression [2], Naïve Bayes and K-Nearest Neighbor (KNN) [3][4] where it returned a satisfactory recall, F1-score and accuracy. SVM outperforms Gaussian kernel and Naïve Bayes by producing a root mean squared error of 15.7% and 22.62% respectively [5]. Another article [6] compares SVM with NB and proves that the former provides better results than latter.

Text classification is a sub-area of Natural Language Processing, where a classifier is used to study a text and then assign a category to that document. It is also known as text categorization or document categorization. There is a lot of data out there which is not eligible for use until it is classified into a proper category and gets structured and organized. Data is properly categorized after doing text classification can be used in many places such as Sentimental analysis, Movie Reviews and many more.

The main contributions in this work are:

1) BNS and TF-IDF along with Ensemble Learning is applied to reduce the misclassification and increase the accuracy of the SVM model. This model is tested on a Spam text classification dataset from Kaggle which is a binary dataset. The results give the inference that TF-IDF will always work better than BNS scaling and the proposed model where TF-IDF along with the Voting Classifier is used shows the best performance.

2) Genetic Algorithm along with OneVsRest classifier is applied to increase the performance of labelled dataset when the provided dataset has limited labelled tuples and more un-labelled tuples. This enhances the performance of classifying multilabel multi-instance classification. It is tested on the Reuters dataset.

The organization of the rest of the paper is given here: Section 2 contains Literature survey of the research regarding the subject. Section 3 comprises the methodology of the proposed approaches. Section 4 contains the evaluated results. Section 5 concludes the paper.

II. Literature Survey

Text classification is the process of categorizing documents. This task is imperative in companies that demand classifying data to ease managing them. SVM is a contemporary approach that is applied to classify the textual content. Although, SVM outperforms a number of algorithms, it becomes challenging to draw the decision boundary as SVM requires identifying the support vectors and then classifying the data. Articles [7][8][9] applies feature scaling using TF-

IDF and neglects to scale the words appropriately. The article [7] came up with a new method of converting words into vectors known as BNS. BNS scaling is a weighting term proposed by HP labs and is applied in most of the research articles. In it BNS score for each of the feature words is calculated and then TF-BNS is used instead of IDF for a better scaling. The difference value between the inverse normal cumulative function of TPR (true positive rate) and FPR (false positive rate) is used as a BNS score. When tested, performance metrics of BNS were better than all other algorithms such as TF, IDF and TF*IDF. It's also a proven fact that, TF and IDF when applied individually delivered better accuracy than TF*IDF.

The article [8] applies the weighting algorithm TF-RF (Term frequency relevance frequency) which proved to be better than TF-IDF as it improves the effect of identifying the discriminating terms. Approaches like Word2vec (a google product) or latent semantic indexing is combined with TF-IDF to bring an extra feature that helps to train SVM further for text classification [10]. However, it becomes arduous for SVM to classify the data, if there are not enough features or the dataset is not big enough for training [11][12].

Hybrid models and hierarchical models were developed to overcome the problem of misclassification of data points that lie near the decision boundary. SVM is combined with decision trees in [13][14], with random forest in [15] and both the models were too complex and took increased training time. The former applied SVM in each node of the Decision tree to separate some group of/individual classes from the rest. Accuracy score of DT+SVM was better than Naïve Bayes, standard SVM and standard DT. The latter extended this idea and applied RF. This model reduced the misclassifications near the decision boundary and performed exceptionally well for only large datasets. However, when this method was tested on an average sized dataset, it did not have a good accuracy score. SVM in hierarchies were applied in [16][17] and produced trivial results than those produced by decision trees and random forest.

A hybrid model of SVM with KNN (K-Nearest Neighbor) is proposed in [18]. The concept of incremental learning is applied to speed up the process of training. Results showed that the F1-score of the hybrid model was better than standard SVM as well as standard KNN.

It's well known that SVM is a supervised ML algorithm which can show remarkable performance when executed with appropriate kernels. An experiment using 4 different kernels-Linear, Polynomial, Gaussian and Sigmoid is done in [19]. Results showed that the Gaussian (Radial Basis Function) kernel produced good results for text classification. For multiclass classification, either OneVsOne and OneVsRest classifiers are preferably applied. The author in [19] substantiates that OneVsRest is much more robust when it comes to classification of categories that have a very small number of documents for training. OneVsRest was compared with OneVsOne for multiclass classification in [20] and the author compared four different algorithms for multiclass classification and accuracy was measured. OneVsRest showed 98% accuracy and proved better than other algorithms.

III. METHODOLOGY

In the proposed model, SVM, BNS, AdaBoost and Voting Classifier are applied for text classification. A brief description of all the algorithms used is given here.

A. Support Vector Machine

SVM, a supervised ML algorithm is applied both in Regression and classification. SVM creates a hyperplane/decision boundary for a 2D/nD data, such that classes are separated as widely as possible. It identifies the support vectors to create a margin that is as wide as possible (Fig. 1).

Compared to other classification algorithms SVM is much faster, accurate and handles well the problem of overfitting. SVM being a binary classifier limits it for certain applications. Yet SVM can be combined with many other algorithms such as OneVsOne and OneVsRest which enables it for multiclass classification. In the proposed algorithm, OneVsRest algorithm is applied over Reuters dataset.

B. Bi-Normal Separation

BNS is applied for term weighting and overcomes the problem faced by IDF (Inverse Document Frequency), i.e., inappropriate scaling of some terms. Formula used by them for assigning a score to a word is given here.

$$|f(TPR)-f(FPR)| \quad (1)$$

f is the inverse normal cumulative distribution function.

Let p = total documents categorized as positive class in training dataset, n = total documents categorized as negative class in training dataset, tp = True positives: number of documents of positive class label which comprises the ‘word’, fp = False positives: number of documents of negative class label which comprises the ‘word’.

$$fn=p-tp, \quad tn=n-fp \quad (2)$$

tpr = Probability that word is present in a document, given the document belongs to the positive class label.

$$tpr=tpp \quad (3)$$

fpr = Probability that word is present in a document, given the document belongs to the negative class label

$$fpr=fpn \quad (4)$$

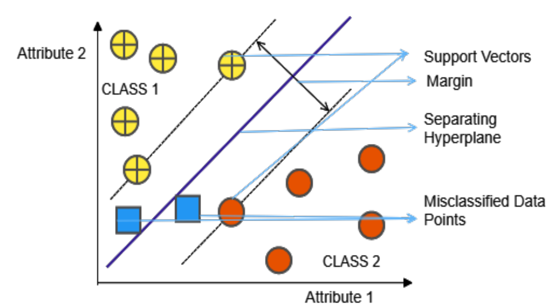

Fig. 1. Support Vector Machines.

C. AdaBoost

Ensemble Learning is a type of learning which combines many weak classifiers to form a strong classifier. Weak classifiers have low accuracy and strong classifiers have high accuracy. Ensemble Learning is of 3 different ways, i.e., Bagging, Boosting and Stacking. In the proposed method Boosting is applied. Boosting is an Ensemble Learning approach which helps us to create more accurate classifiers with minimal error. Boosting algorithms are less prone to overfitting problems. AdaBoost is a boosting algorithm which aims to fit the training set in a better and more accurate way after each iteration/pass (to other classifiers). It constantly increases the weights of misclassified points, and this modified dataset with modified weights is passed onto the next weak classifier. This is a sequential kind of process, where the output of one classifier becomes the input of another (Fig. 2). This process will terminate when the maximum number of classifiers are reached, or the dataset fits completely.

D. Voting Classifier

Voting Classifier works similar to real life elections. A person who gets the majority of votes wins and in a similar way the outcome which is predicted by majority of classifiers is given as final output. It strives to increase accuracy. Since predictions of many classifiers are being considered, voting classifiers help in decreasing the error rate thereby minimizing the chance of misclassification. In (Fig. 3), a simple working of Voting Classifier is explained.

E. Classification using Ensemble Learning on applying TF-IDF and BNS

One of the prevalent challenges of SVM mentioned by many research papers is that SVM does misclassification when the test data tuple lies within the area of hyperplane. To overcome this drawback, a Voting classifier along with the AdaBoost algorithm is used so that the misclassifications would be reduced.

1) Dataset: The spam text classification dataset was chosen to test the proposed method 1. The dataset is split into 2 halves. 80% of the dataset is used for training purposes and 20% of the dataset is used for testing purposes. The Table I shows the train test split ratio of the number of tuples.

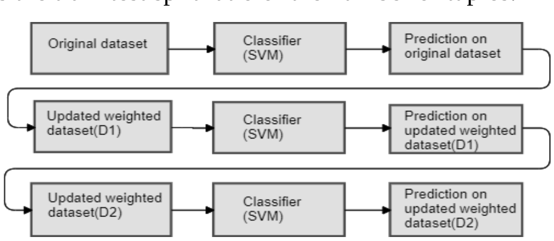

Fig. 2. Adaboost with SVM.

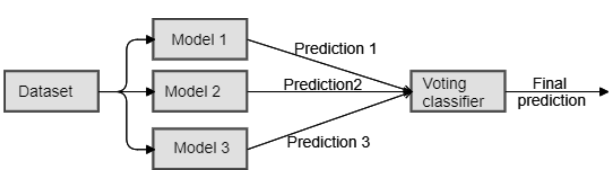

Fig. 3. Voting Classifier.

TABLE I. TRAINING-TEST DATASET SPLIT

Dataset splits	*Number of tuples*
X_{train}	4457
Y_{train}	4457
X_{test}	1115
Y_{test}	1115

2) Proposed ensemble algorithm: As already mentioned about the key features of BNS, BNS scaling for feature scaling/term weighting (word to vector) is applied to improve the accuracy of SVM. Following steps are done in the proposed algorithm:

Step 1: Firstly, preprocessing (Fig. 4) is applied on the whole initial dataset D.

Step 2: Now the preprocessed dataset D is split into 2 datasets: D_{train} and D_{test}. Following which, the featured words are converted into vectors using both TF-IDF and BNS, in order to compare the difference in accuracy.

Step 3: AdaBoost classifier that uses SVM with kernel as RBF function (Gaussian function) is applied. The classifier takes a number of iterations to fit the dataset.

Step 4: Succeeding, a Random Forest is created. Though random forest takes a longer time to train and predict as compared to a single decision tree classifier, it also has the advantage that it gives better accuracy.

Step 5: In the final ensemble model: AdaBoost, Random Forest, SVM and Decision Tree are combined together. This ensemble model is used as Voting classifier. The generated ensemble model is trained and the results of the prediction are obtained.

Step 6: Standard SVM with RBF kernel is applied on both the datasets (dataset converted using BNS and dataset converted using TF-IDF) and the results of the prediction are obtained.

Step 7: The accuracy score of both the classifiers 'Voting Classifier' and 'SVM with RBF kernel' is compared.

In the (Fig. 5) above, you can get a better diagrammatic representation of framework-1.

In this Section, ensemble learning along with TF-IDF as well as BNS is applied and the results of TF-IDF were better than BNS. Henceforth in the next section TF-IDF is applied to classify multi class dataset using SVM.

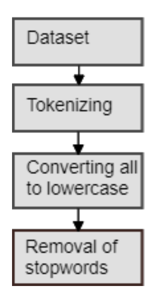

Fig. 4. Steps Involved in Pre-processing.

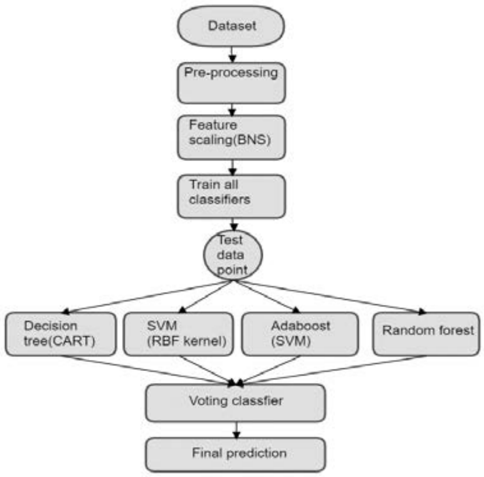

Fig. 5. Framework-1.

F. Genetic Algorithm over SVM

Genetic Algorithm (GA) has been used in many Artificial Intelligence (AI) applications for generating dataset. They were used in many applications such as training of Recurrent Neural Networks, GBML (Genetic Based Machine Learning Algorithm) and DNA Analysis, etc.

This concept is applied in the framework to create a sample labelled dataset which can be used to train the Machine Learning algorithm in a much better manner. There are many instances when due to unavailability of proper labelled dataset, the accuracy is not to satisfiability level. By unavailability, it means reduced number of tuples for training a particular class label or reduced features and comparatively smaller number of tuples. The framework aims to solve the hypothesis where the tuples are more, with few labelled and rest un-labelled.

1) Dataset: To create a temporary label for some random un-labelled tuples, which can further help us to achieve greater stability, the following steps are applied over the Reuters dataset. It has a total of 7769 documents for training purposes and 3019 documents for testing purposes. Out of these 7769, 2590 documents are taken as labelled and out of the remaining 5179 documents, 740 documents are taken as unlabeled ones. For these unlabeled ones we will run the genetic algorithm and try to create a label which will be as close to the real label as possible. Reuters dataset has a total of 90 classes in it. The dataset split is shown in Fig. 6 and Fig. 7.

On applying K- Nearest Neighbors and Decision Trees over 3019 documents the accuracy obtained was 8.07 and 9.13 respectively. This poor accuracy value motivated us to apply genetic algorithm over SVM for further classifying the tuples. Our framework improves the accuracy of classification.

2) Proposed genetic algorithm for classification: Objective: To label the unlabeled tuples and to arrive in generating an SVM model that classifies the tuples with maximal accuracy. It is implemented over Reuters Dataset.

Step 1: Split the initial dataset D into two parts: $D_{labeled}$ and $D_{unlabeled}$. As Reuters is a labelled dataset, tuples (text document) are randomly picked from the Reuters dataset, remove their labels and store in $D_{unlabeled}$.

Step2: To convert the labels of the dataset $D_{labeled}$ to numeric values, MultiLabelBinarizer is used (As the objective is to perform Multi class classification).

Step 3: Text documents of datasets $D_{labeled}$ and $D_{unlabeled}$, are preprocessed, i.e., operations in the (Fig. 4) are done on the datasets before the words are converted to a suitable numeric/binary type.

Step 4: Feature scaling (converting words into vectors) is applied on datasets $D_{labeled}$ and $D_{unlabeled}$ by applying TF-IDF. Further the dataset, $D_{labeled}$ is split into training $D_{labeled}$ dataset and test $D_{labeled}$ dataset. Preprocessing the data involves the same steps that were shown in Framework-1.

Step 5.a: Let the number of tuples in the unlabeled dataset be T. For each of these tuples the labels are predicted using a random prediction approach.

Step 5.b.: Train an SVM classifier, x on the tuples labelled in step 5, and classify the labelled tuples.

Step 5.c: Calculate the accuracy and fitness score of the SVM classifier, x.

Step 6. Run the step 5 for N times. This is the completion of one generation. At the end of the generation, the fitness score of N SVM classifiers is obtained.

$$fitness\ score = \{SVM-1, SVM-2, \ldots, SVM-N\} \quad (5)$$

Fitness score is a measure of accuracy that the model shows on labelled dataset.

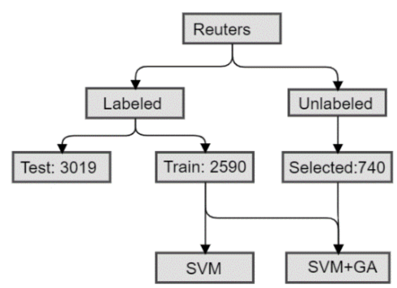

Fig. 6. Tree Representation of Smaller Dataset.

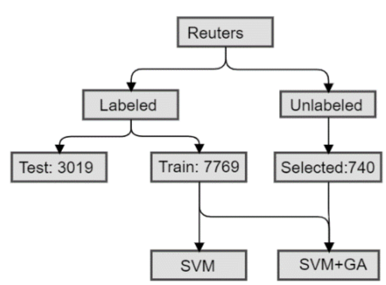

Fig. 7. Tree Representation of Bigger Dataset.

Step 7: After calculating the fitness score of each classifier, the mating pool is created. The purpose of mating pool is to identify the two SVM classifiers that has highest accuracy among N other SVM classifiers

$$fitness\ score = \{SVM - 1 > SVM - 2 > \cdots SVM - N\} \quad (6)$$

Here the models are arranged in decreasing order of their fitness scores.

Step 8: Now starts the Genetic algorithm operations

Step 8.a: Crossover: The crossover is done on the labels of the tuples generated by the top two classifiers chosen in Step 7. An initial probability, p, for cross over is chosen by the algorithm during runtime. The value of p decides crossover between the results of the two classifiers. If it is lower than the number expected, crossover is performed otherwise the parents are passed on as the off springs (new population) (Fig. 8).

Step 9: Mutation: Randomly change the values of the labels classified by the SVM and this represents the new set of labels for the unlabeled dataset. A mutating variable, p1 acts as a deciding factor to change the values of the tuples (Fig. 9).

Step 10: Step 5 to Step 9 is named as one generation in GA. Check if the number of generations, G is reached. The value of G is decided based on the accuracy of the final classifier generated. If not, then go back to step 5, otherwise move on go step 11.

Step 11: At the end of G generations, all the labelled tuples of the unlabeled dataset is moved to train $D_{labeled}$ dataset.

Step 12: An SVM is trained on the new train $D_{labeled}$ dataset and the performance is measured.

Step 13: Test this classifier on the test $D_{labeled}$ dataset and the performance is measured.

The generated SVM on applying TF-IDF and GA classifies the documents into 90 classes and produces better accuracy.

In the (Fig. 10), the diagrammatic representation of the algorithm used is shown.

Before Cross-over:

Labels of first best SVM	$Te1_1$	$Te1_2$	$Te1_3$	...	$Te1_{369}$	$Te1_{370}$	$Te1_{371}$	$Te1_{372}$	...	$Te1_{740}$
Labels of second Best SVM	$Te2_1$	$Te2_2$	$Te2_3$	...	$Te2_{369}$	$Te2_{370}$	$Te2_{371}$	$Te2_{372}$	...	$Te2_{740}$

After Cross-over:

Labels of first best SVM	$Te1_1$	$Te1_2$	$Te1_3$	...	$Te1_{369}$	$Te2_{370}$	$Te2_{371}$	$Te2_{372}$	...	$Te2_{740}$
Labels of second best SVM	$Te2_1$	$Te2_2$	$Te2_3$	...	$Te2_{369}$	$Te1_{370}$	$Te1_{371}$	$Te1_{372}$	...	$Te1_{740}$

Fig. 8. Cross-over.

Before Mutation	Te_1	Te_2	Te_3	Te_4	Te_5	Te_6	Te_7	...	Te_{739}	Te_{740}
After Mutation	Te_1	Te_2	Te_3	Te_4	Te_5	Te_6	Te_7	...	Te_{739}	Te_{740}

Fig. 9. Mutation.

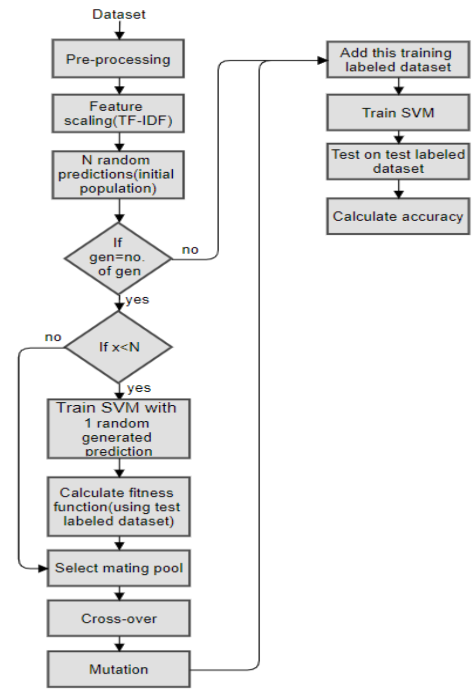

Fig. 10. Framework-2.

IV. Implementation and Results

In this section the performance of frameworks is evaluated based on evaluation metrics:

A. Performance Metrics

In the following section, a brief explain about the performance metrics used is given.

Accuracy and F1-score will be used to compare the performance of the proposed and existing frameworks.

Accuracy can be defined as correctly classified points over total instances in the dataset.

Accuracy= True Positive + True Negative / True Positive + True Negative + False Positive + False Negative (7)

Precision is the ratio of correctly predicted positive instances over total predicted positive instances.

Precision=True Positive / True Positive + False Positive (8)

Recall is the ratio of correctly predicted positive instances over actual positive instances.

Recall= True Positive/True Positive + False Negative (9)

F1-score takes both false positives as well as false negatives into account. For a good F1-score, good precision as well as good recall is needed. Having a model with good F1-score will be better than the one with lower F1-score. F1-score is 2 times the inverse of harmonic mean of Precision and Recall.

F1-score= (2* Precision * Recall)/ (Precision + Recall) (10)

TABLE II. CONFUSION MATRIX FOR FRAMEWORK-1

		Existing Model		***Proposed Model***		***Existing Model***		***Proposed Model***	
		SVM(BNS)		***VC(BNS)***		***SVM(TF-IDF)***		***VC(TF-IDF)***	
		Predicted Class Label							
Actual Class Label		***0(Not Spam)***	***-1(Spam)***	***0(Not Spam)***	***-1(Spam)***	***0(Not Spam)***	***-1(Spam)***	***0(Not Spam)***	***-1(Spam)***
	0(Not spam)	0	0	0	0	130	2	131	2
	-1(Spam)	161	954	149	966	19	964	17	965

B. Confusion Matrix of all the 4 Models BNS vs TF-IDF

The evaluated model's confusion matrix is given in Table II. The spam text is classified into two classes: spam and not spam. The contemporary SVM with BNS and TF-IDF is compared with the proposed Voting Classifier with BNS and TF-IDF.

C. Tabulated Results of Framework-1

The results of the framework-1 are tabulated in Table III. It is found that accuracy score and F1-score of models when TF-IDF is used much better than the models when BNS is used.

Another notable feature is that Voting Classifiers perform better than SVMs. TF-IDF when used with Voting Classifier shows the best results. Therefore, TF-IDF gives better real valued representation of textual data when converted into vectors.

The following figures (Fig. 11 and Fig. 12) show the Accuracy scores and F1-scores of all the 4 models.

1) SVM (RBF kernel) with BNS
2) VC with BNS
3) SVM (RBF kernel) with TF-IDF
4) VC with TF-IDF

TABLE III. PERFORMANCE METRIC VALUES OF THE 4 MODELS

Models/Evaluation Metrics	***Accuracy***	***F1-score***
SVM(BNS)	85.6%	91.2%
VC(BNS)	86.3%	92.8%
SVM(TF-IDF)	98.11%	98.2%
VC(TF-IDF)	98.26%	98.9%

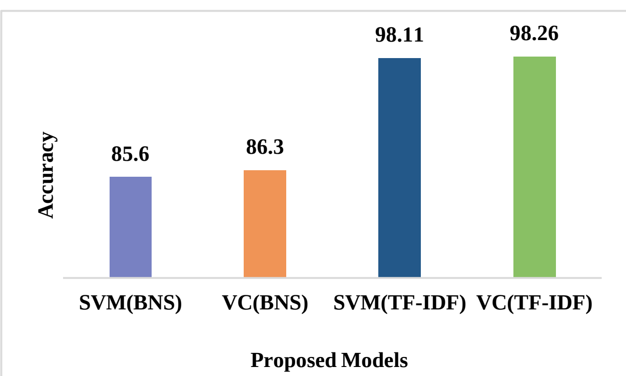

Fig. 11. Accuracy Measures of Framework-1.

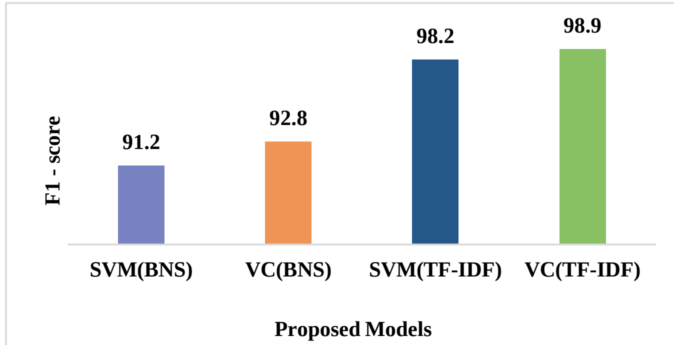

Fig. 12. F1-scores of Framework-1.

TABLE IV. PERFORMANCE METRIC VALUES OF SVM AND SVM+GA OVER SMALLER DATASET, 1- GENERATION AND 3- GENERATIONS

	1-generation		**3-generation**	
Models/Evaluation Metrics	***Accuracy***	***F1-score***	***Accuracy***	***F1-score***
SVM	6.12%	11.59%	6.12%	11.59%
SVM+GA	20.07%	27.98%	36.52%	42.82%

D. Tabulated Results of Framework-2

On applying genetic algorithms over SVM, the performance of the system shows greater increase with small labelled dataset. Accuracy and F1-scores of SVM applied over small labelled dataset (Table IV) are 6.12% and 11.59% whereas SVM+GA are 20.07% and 27.98%. As we can see that when GA is implemented for 1 generation and 3 generation, there is a huge difference between the results of SVM and proposed methods in terms of evaluation metrics. The GA is applied on a smaller dataset to show the increase in the performance.

Over the complete Reuters dataset SVM and SVM + GA is applied and the performance is measured and Tabulated in Table V. It's found that with GA, a substantial increase in accuracy is found, as because GA learns the pattern of allocating labels to the unlabeled data that are much closer to the original labels.

TABLE V. PERFORMANCE METRIC VALUES OF SVM AND SVM+GA OVER COMPLETE DATASET, 1- GENERATION AND 3- GENERATIONS

	1-generation		**3-generation**	
Models/Evaluation Metrics	***Accuracy***	***F1-score***	***Accuracy***	***F1-score***
SVM	86.53%	88.12%	86.53%	88.12%
SVM+GA	90.37%	91.45%	93.88%	96.72%

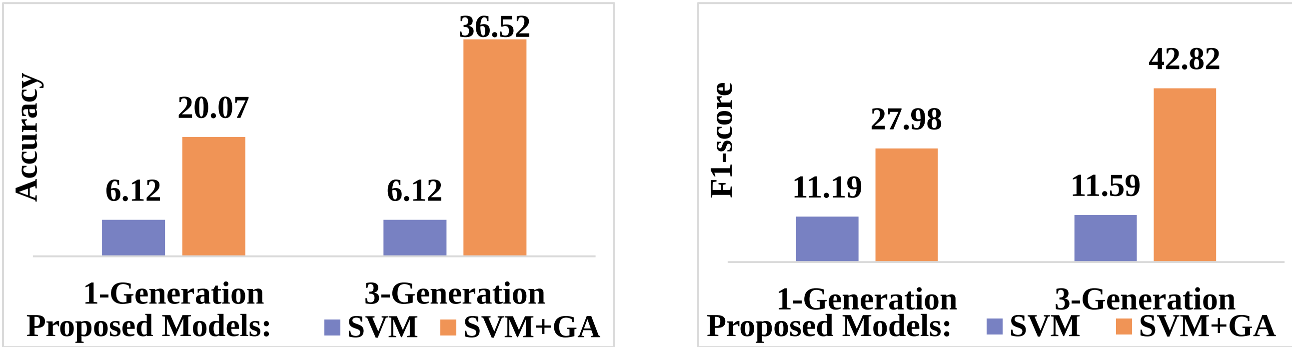

Fig. 13. Accuracy and F1 Score of Measures of Framework-2 with a Small Labelled Dataset.

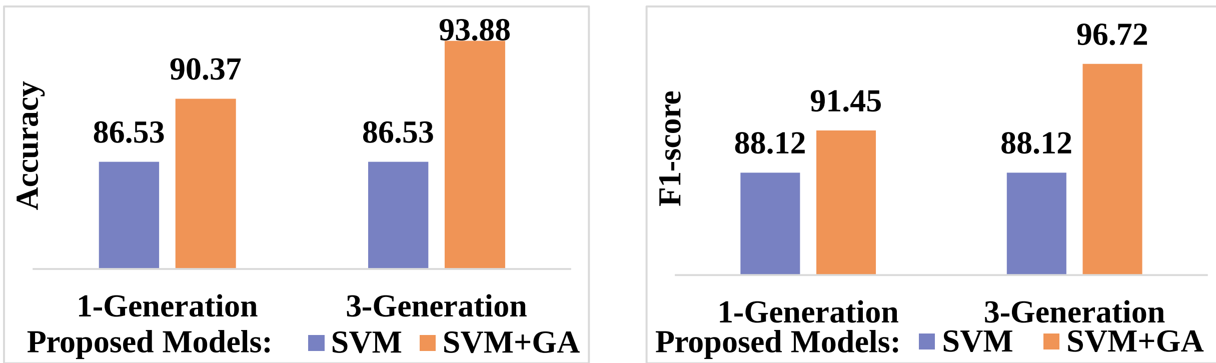

Fig. 14. Accuracy and F1 Score of Measures of Framework-2 with a Large Labelled Dataset.

Following figures (Fig. 13 and Fig. 14) show the graphical representation stating the accuracy and F1- score of SVM and SVM+GA with small and large labelled dataset.

V. Conclusion

This paper proposes two algorithms for binary and multi-class text classification. The two-vector representation of textual data: TF-IDF and BNS is explored and is identified that TF-IDF produces good results than BNS. The contributions are made in two-fold. The first proposed algorithm is the voting classifier that is created with four different classifiers. It is tested on Spam Text classification dataset from Kaggle. From results it is found that the use of TF-IDF improves the accuracy than BNS and the results ensured that Voting Classifier when used along with TF-IDF will give best accuracy (98.26%). The second algorithm classifies the dataset with limited number of labelled training samples. This algorithm applies Genetic Algorithm to generate labels for unlabeled datasets over which SVM is applied. Cross over and Mutation are the genetic operations that are applied in many generations. The results are measured in two folder: with smaller labelled dataset and with larger labelled dataset. With a small labelled dataset, an increase of accuracy from 6.12 % to 20.07% is found with one generation and 6.12 % to 36.52% with three generations on applying SVM and SVM+GA. With a large labelled dataset, an increase of accuracy from 86.53% to 90.37% is found with one generation and 86.53% to 93.88% with three generations on applying SVM and SVM+GA. This proposed algorithm is applied on the Reuters dataset. An increase in generation and on application of GA operations might slow down that process but has a positive side that helps in increasing the accuracy by a good margin. The future scope will be to incorporate genetic algorithm along with neural networks for the task of Text Classification. We also aim to research on using different pre-processing steps that will enhance the model's performance metrics score.

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Object Detection Approaches in Images: A Weighted Scoring Model based Comparative Study

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***Abstract*—Computer vision is a branch of artificial intelligence that trains computers to acquire high-level understanding of images and videos. Some of the most well-known areas in Computer Vision are object detection, object tracking and motion estimation among others. Our focus in this paper concerns object detection subarea of computer vision which aims at recognizing instances of predefined sets of objects classes using bounding boxes or object segmentation. Object detection relies on various algorithms belonging to various families that differs in term of speed and quality of results. Hence, we propose in this paper to provide a comparative study of these algorithms based on a set of criteria. In this comparative study we will start by presenting each of these algorithms, selecting a set of criteria for comparison and applying a comparative methodology to get results. The methodology we chose to this purpose is called WSM (Weighted Scoring Model) which fits exactly our needs. Indeed, WSM method allows us to assign a weight to each of our criterion to calculate a final score of each of our compared algorithms. The obtained results reveal the weaknesses and the strengths of each one of them and opened breaches for their future enhancement.**

***Keywords*—Computer vision; object detection; images; WSM method; object detection algorithms**

I. Introduction

Object detection consists of several subtasks such as face recognition, pedestrian detection, skeleton detection, etc., and has use cases such as surveillance systems, autonomous cars, etc.[1][2]. There are two types of approaches to object detection in images: one based on two-stage detectors and the other based on one-stage detectors. One-step object detection algorithms work by immediately detecting objects on a sample of possible locations such as Fast R-CNN [3], R-CNN [4], Faster R-CNN [5], etc. Two-step object detection algorithms will first propose a set of regions of interest and then rank the relevant regions such as SSD [6], YOLO [7], CenterNet [8], etc. The architectures of these algorithms differ from each other in terms of accuracy, speed, and required hardware resources.

These approaches rely on deep learning models that are capable of end-to-end object detection, as they use a multi-layer structure of algorithms called neural networks that allow to perform many tasks, such as clustering, classification, or regression. A neural network is composed of input, hidden and output layers, all of which are composed of "nodes" as shown in Fig. 1.

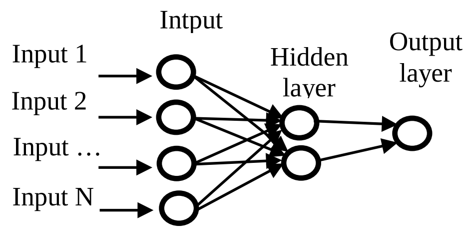

Fig. 1. A Simple Neural Network.

This paper, therefore, proposes to compare these algorithms based on the Weighted Scoring Model (WSM). Hence, we begin our comparative study by extracting the most relevant criteria for comparison and justify our choice for each criterion. Next, we present the WSM method before moving to assigning weights to each criterion and obtaining final scores for the compared object detection algorithms that are finally represented using a spider graph. The purpose of this spider graph is to show us the best detection model according to a set of scores for each criterion such as accuracy, speed, etc.

The document is organized as follows: Section II describes works related to our topic; Section III presents a background of object detection algorithms; Section IV presents our comparative study of object detection algorithms; Section V discusses the outcomes of this study and finally in Section 6 we draw a conclusion.

II. Related Work

Object detection is a challenging task that arises in many image processing applications such as human-computer interaction, civil and military surveillance, virtual reality, and human motion analysis or image compression. This challenge rises in unconstrained environments where the tracking system will have to adapt to important variability of objects, to variations of luminosity, to occlusions (partial or total) as well as to motion detection problems.

The introduction of deep learning algorithms, especially CNNs, to computer vision problems has progressed rapidly which has led to very robust, efficient, and flexible vision systems. Since the results of the "ImageNet 2012 challenge" event [9], Deep Learning and especially convolution networks have become the best method to solve this kind of problem.

Object detection is a very active field of research that seeks to classify and locate regions/areas of an image. This field is at the crossroads of two others: image classification and object localization [11]. Research in object detection has naturally integrated image classification models, which has led to the creation of models such as SSD [6] and R-CNN [4], etc.

Many scientific works are aimed at discovering approaches to object detection in images and algorithms and techniques that exist in each approach. Many researchers have made scientific efforts in this area to compare and show advantages and disadvantages of each algorithm and techniques that detect objects in images. Several research works tried to compare algorithms and models for object detection in images [7][6][12][13][14][15].

Sanchez et al. [16] have performed a review of state of the art related to the performance of pre-trained models for object detection in order to make a comparison of these algorithms in terms of reliability, accuracy, time processed, and problems detected. In this research [16], different pre-trained models using two datasets MS COCO[17] and PASCAL VOC[18] have been reviewed for object detection such as R-CNN, R-FCN, SSD, and YOLO, with different feature extractors such as VGG16, ResNet, Inception, MobileNet.

Srivastava et al. [19] were presented a comparative analysis of 3 major image processing algorithms: SSD, Faster R-CNN, and YOLO. In this analysis, they chose the COCO dataset to evaluate the performance and accuracy of the three algorithms and analyzed their strengths and weaknesses. They implemented these models and based on the results obtained, they determined the differences between the performance of each algorithm and the appropriate applications for each. The evaluation metrics are accuracy, precision, and F1 score.

In this work by Gupta et al.[20], the COCO dataset was used to extract sample images and then they used three architectures and three extractors to build different combinations of models in order to calculate the speed and accuracy (mAP) of each of these models.

All these comparative studies are based on the results of the implementation of each model used. For the comparison criteria, they focused on two criteria: accuracy (mAP) and speed. Most of these studies compared two-step detector-based approaches with one-step detector-based approaches.

The authors show that single-stage detectors are divided into two types [21][12]: Detectors with anchors and detectors without anchors, these two types each have advantages and disadvantages. The first major problem with anchored detectors is the involvement of several hyperparameters, which makes the algorithms very slow and computationally intensive [12]. This results in a low accuracy rate and makes the unanchored detectors outperform the anchored detectors. The best-known models in this approach are: YOLO [7], CenterNet [8], CornerNet [22], FCOS [12], etc. Then, they showed that the principle of two-stage detectors is that the first stage generates a set of regions of interest by the region proposal network (RPN) and the second stage for the classification of regions of interest. Among the algorithms that are based on this principle, we have R-CNN [21], Faster R-CNN [5], etc.

Our work is also based on the comparison of these approaches and algorithms based on the results of the implementations of previous works, and then according to a set of criteria, besides these two criteria: Average Accuracy (AP) and Speed (FPS), we have other criteria that we will discover in Section IV. What distinguishes our work from the others mentioned above is that this work uses the Weighted Scoring Model (WSM) which is one of the multi-criteria decision analysis methods. This method is adopted to make this comparison and get the work that is more favored for most of the criteria and discuss the result of this comparison.

III. Object Detection in Images

Object detection and recognition are computer vision techniques that allow the detection of object instances in images or videos [23].

Models and techniques for object detection in images generally use extracted features and learning models to recognize instances of classes of objects. These models are based on convolutional neural networks known as CNNs, which can vary in architecture, which play a key role in the construction of algorithms, but the basic principle remains the same [23].

A. Background

1) Convolution neural network (CNN): CNNs are one of the most popular classes of neural networks, especially for high-dimensional data (e.g., images and videos). CNNs work very similarly to standard neural networks. A key difference, however, is that each unit in a CNN layer is a two-dimensional (or high) filter convolved with the input to that layer. This is essential in cases where we wish to learn patterns from high-dimensional input media, such as images or videos. CNN filters incorporate spatial context by having a similar (but smaller) spatial shape as the input media, and use parameter sharing to significantly reduce the number of variables that can be learned [24].

CNNs can vary in architecture that play a key role in building algorithms, but the basic principle remains the same. Fig. 2 shows the Convolutional neural network architecture. It receives an input feature map, i.e., a three-dimensional matrix whose size of the first two dimensions corresponds to the length and width in pixels of the images.

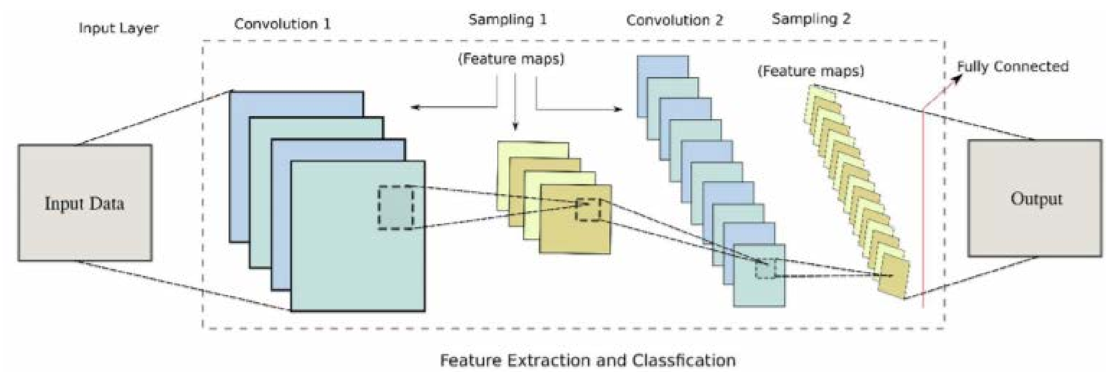

Fig. 2. CNN Architecture[10].

The size of the third dimension is three corresponding to the three channels of a color image: red, green, and blue. After this feature map, there are:

- Convolutional layer: The role of this layer is to extract fields from the input feature map and apply filters to them to compute new features, thus producing a convolved feature map.
- Max Pooling: The goal of this layer is to minimize the dimensions of the input while preserving as much information as possible because the processing of the convolutional layer is a very computationally expensive operation. And for this purpose, pooling is one of the techniques used to minimize the dimensions.
- Fully connected: After these previous layers, we have this layer whose role is to perform a classification based on the features extracted by the convolutions. And generally, this layer contains a SoftMax activation function, which provides a probability value between 0 and 1 for each of the classification labels that the model tries to predict.
- Output layer: this layer shows the result, i.e., the result of the classification algorithm used.

2) Region proposal network (RPN): Region Proposal Network (RPN) [5] is a fully convolutional network that simultaneously predicts object boundaries and objectivity scores at each position. It is trained end-to-end to generate high quality region proposals, used with the Fast R-CNN model that was proposed by[3] for object detection in images and reduces the number of candidate object locations by filtering out most background samples. This network is essential in the architecture of Faster R-CNN model which has been improved by researchers [5]. Fig. 4 shows the principle of Region Proposal Network.

3) Feature pyramid network (FPN): Feature Pyramid Network (FPN) [25] is a feature extractor and generates multiple layers of feature maps with better quality information than the regular feature pyramid for object detection. FPN consists of a bottom-up and top-down path. For the bottom-up path, it is the usual convolutional network for feature extraction. As we go up, the spatial resolution decreases, and with more high-level structures detected, the semantic value of each layer increases. For the downward path, it is to build higher resolution layers from a semantically rich layer. Some simultaneous works like RetinaNet [13] also use this type of network. Fig. 3 shows the Feature Pyramid Network architecture.

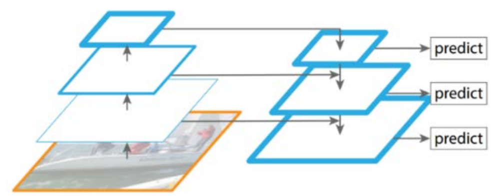

Fig. 3. Feature Pyramid Network (FPN).

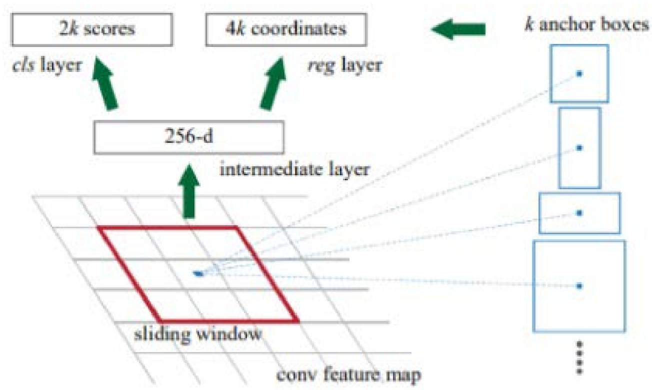

Fig. 4. Region Proposal Network (RPN).

B. *Principle of Staged Detectors and their Advantages and Disadvantages*

Object detection approaches in images are divided into two categories: approach based on two-stage detectors and approach based on one-stage detectors. Each approaches contains many models, in Section IV, we will detail and compare these models.

1) Two-stage detectors: The principle of two-stage detectors is that the first stage generates a set of regions of interest using Region Proposal Network (RPN), which reduces the number of candidate object locations by filtering most of the background samples. The second step is the classification of regions of interest among candidate object locations extracted in the first step [23].

The advantage is that the models and algorithms that exist in this approach such as: : R-CNN [21], R-FCN [15], Fast R-CNN [3], Mask R-CNN [26], etc., have a high accuracy but the disadvantage is that at the level of processing time of each image is very slow due to repetitive detection and classification [23]. In Table II, we will list advantages and disadvantages of one and two-stage detectors.

2) One-stage detectors: The main goal of one-step detectors is to unify detection and classification in one step which will result in a single pass through the neural network. Thus, it predicts all candidate object locations at once which increases the speed of object detection [23] but on the other hand, they suffer low accuracy. The most known models in this approach are: YOLO [7], RetinaNet [13], SSD [6], CenterNet [8], etc.

One-stage detectors are divided into two types: Anchor-based detectors [27] and others anchor not based detectors. For Anchor-based detectors, the detection is done by a frame around the detected objects [23]. This frame is called an anchor or bounding box as seen in this figure. Concerning, anchor-not-based detectors, the detection is made by a point in the center of the detected object. The first major problem with anchor detectors is the involvement of several hyperparameters, which makes the algorithms very slow and requires much computation power. This results in a low rate of accuracy and makes anchorless detectors outperform anchor detectors [23].

IV. Comparison of Object Detection Approaches in Images

Comparison of object detection models in images is based on the WSM method which allows to differentiate between compared objects according to a set of criteria [28].

A. Weighted Scoring Model

Weighted scoring model [29] is a project management technique that combines quantitative and qualitative measures to facilitate operational decision-making and allows multiple criteria to be considered. Specific scoring criteria can be selected based on well-defined objectives and product metrics.

This technique assigns a weight to each criterion based on its relative importance, with the most important criterion being assigned the highest weight. To realize the application of the WSM method, we have four steps to follow [28]:

- Step 1: Select a list of features and other initiatives being considered.
- Step 2: Select criteria, including costs and benefits, on which you will evaluate each of these initiatives.
- Step 3: Determine the respective weighting of each criterion that you will use to evaluate your competing initiatives.
- Step 4: Assign individual scores to each feature, for all your cost and benefit criteria, and then calculate these overall scores to determine the ranking of the list of features.

1) Comparison criteria: Each approach contains many different models as presented in the sections above, and each model has a set of criteria that help the user to make the decision to choose the best performing and most adaptable model for his project. The choice of criteria for comparing each model is extracted from previous work that has enriched the object detection domain. We have identified five criteria:

- Average Accuracy (AP): This criterion indicates the accuracy value of each object detection model. It depends on the quality of the input images, the number of training samples, the model parameters, and the required accuracy threshold. The values presented in Table IV of this criterion are scores from 1 to 5 according to the following intervals to which the accuracy value (AP) of each model belongs.
- Detection time (FPS): This criterion indicates the number of frames processed per second for each object detection model. It expresses the processing speed of the model. In Table IV, the values presented of this criterion are scores from 1 to 5 according to the following intervals to which the SPF value of each model belongs.
- Real-time: This criterion shows how well the model works for real-time object detection. This criterion is evaluated in three values: 1 which means poor, 4 which means fair, 5 which means good.
- Number of stages: this criterion shows the number of stages of each model and designs the category of detectors. We have two categories: One-stage detectors and two-stage detectors.
- Simple network structure: This criterion shows if the model is easy and simple to use for object detection. This criterion is evaluated as a Boolean value that shows the availability of this criterion for each model.

Table I shows the intervals to which the accuracy value (AP) and detection time (FPS) of each model belong and their scores.

Table IV shows the scores from 0 to 5 of each criterion corresponding to each model according to the evaluation of each criterion that we explained in section 5.1.1.

TABLE I. AP and FPS Scores for each Interval

Intervals	Scores
[0,10]	1
[10,20]	2
[20,30]	3
[30,40]	4
[40,50]	5

TABLE II. ADVANTAGES AND DISADVANTAGES OF OBJECTS DETECTION MODELS

Model / method	**Category**	**Advantages**	**Disadvantages**
Fast R-CNN	Two-stage detectors	High detection accuracy, Low misdetection rate	Non-real-time detection, speed of object detection per image is low
Faster R-CNN			
R-FCN			
Mask R-CNN			
CenterNet	One-stage detectors	Object detection can be in real-time, Simple network structure, speed of object detection per image is high.	Low detection accuracy, Poor results for small and dense objects, Easy to mislocate
CornerNet			
RetinaNet			
YOLO v2			
YOLO v3			
SSD			
FCOS			

TABLE III. VALUES OF THE CRITERIA CORRESPONDING TO EACH MODEL ACCORDING TO THE RESULT OF THEIR IMPLEMENTATION

Criteria	**Fast R-CNN [3] (VGG-16)**	**Faster R-CNN [14] (ResNet-101)**	**R-FCN [15] (ResNet-101)**	**Mask R-CNN [26] [30] (ResNet-101-FPN)**	**CenterNet [8] (DLA-34)**	**CornerNet [14] (Hourglass-104)**	**RetinaNet [13] (ResNet-101-FPN)**	**YOLO v2 [31]**	**YOLO v3 [32](DarkNet-53)**	**SSD [6]**	**FCOS [11] (ResNet-101-FPN)**
AP	35,9	34,9	31,5	35,7	41,6	42,1	40,8	44	33	46,5	41,5
FPS	0,5	5	12	5	28	4,1	5,4	40	20	22	8,1

TABLE IV. COMPARATIVE STUDY OF CRITERIA FOR EACH MODEL

Criteria	**Values of criteria corresponding to each model**										
	Fast R-CNN [3] (VGG-16)	**Faster R-CNN [14] (ResNet-101)**	**R-FCN [15] (ResNet-101)**	**Mask R-CNN [26] [30] (ResNet-101-FPN)**	**CenterNet [8] (DLA-34)**	**CornerNet [14] (Hourglass-104)**	**RetinaNet [13] (ResNet-101-FPN)**	**YOLO v2 [31]**	**YOLO v3 [32] (DarkNet-53)**	**SSD [6]**	**FCOS [11] (ResNet-101-FPN)**
AP	4	4	4	4	5	5	4	5	4	5	5
FPS	1	1	2	1	3	1	1	5	3	3	1
Real-time	1	1	4	1	5	1	1	5	5	5	1
Number of stages	2	2	2	2	1	1	1	1	1	1	1
Simple network structure	0	0	0	0	1	1	1	1	1	1	1

2) Comparative study: The values of the average accuracy (AP) and detection time (FPS) criteria as shown in Table III are extracted from the studies of many researchers that we have already cited in the previous sections. All these models are trained and tested on the same dataset called MS COCO.

MS COCO dataset has been described by Lin et al [17] as a set of data for large-scale object detection, segmentation, and subtitling. It contains a large, richly annotated dataset of images representing complex everyday scenes of common objects in their natural context: photos of 91 types of objects that would be easily recognizable by a 4-year-old child.

B. Application of Weighted Scoring Model

The Table V shows the WSM results for each object detection model in the image. The allocation of weighting percentages is done according to the importance of the criterion. Because of their mandatory nature, priority is given to these two criteria: Average precision (AP) and detection time (FPS), a weight of 0,3 is assigned to each of these criteria. The second category of importance is given to this criterion: Real-time, a weight of 0,2 is assigned to this criterion. The next two criteria are not of great importance: number of stages and simple network structure, each of these two criteria have a weight of 0,1. The weight of the total scores is equal to 1.

TABLE V. RESULTS OF WSM

Criteria	Weight	Requirement score										
		Fast R-CNN [3] (VGG-16)	Faster R-CNN [14] (ResNet-101)	R-FCN [15] (ResNet-101)	Mask R-CNN [26] [30](ResNet-101-FPN)	CenterNet [8] (DLA-34)	CornerNet [14] (Hourglass-104)	RetinaNet [13] (ResNet-101-FPN)	YOLO v2 [31]	YOLO v3 [32] (DarkNet-53)	SSD [6]	FCOS [11] (ResNet-101-FPN)
AP	0,3	1,2	1,2	1,2	1,2	1,5	1,5	1,2	1,5	1,2	1,5	1,5
FPS	0,3	0,3	0,3	0,6	0,3	0,9	0,3	0,3	1,5	0,9	0,9	0,3
Real-time	0,2	0,2	0,2	0,8	0,2	1	0,2	0,2	1	1	1	0,2
Number of stages	0,1	0,2	0,2	0,2	0,2	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Simple network structure	0,1	0	0	0	0	0,1	0,1	0,1	0,1	0,1	0,1	0,1
Weighted scores	1	1,9	1,9	2,8	2,8	3,6	2,2	1,9	4,2	3,3	3,6	2,2

V. DISCUSSION

According to the previous results, the YOLO v2 model is the best performing model for object detection in images. It is a model that was proposed by J. Redmon and A. Farhadi in 2016 in [31].

In terms of speed, this model is one of the best object detection and recognition models, capable of recognizing objects and processing frames up to 40 FPS (in our case) and sometimes up to 150 FPS depending on the architecture used. However, in terms of AP accuracy, YOLO v2 was not the top model but has good accuracy (AP) of 44% when trained on the MS COCO dataset. However, Fast R-CNN, Faster R-CNN which was the state of the art at that time has an AP of 35.9% and 34.9% successively. YOLO v2 belongs to single-stage detectors. Generally, the architecture of this type of detector is simple and easy to use compared to the other models based on two-stage detectors such as Fast R-CNN, Faster R-CNN, R-FCN, and Mask R-CNN.

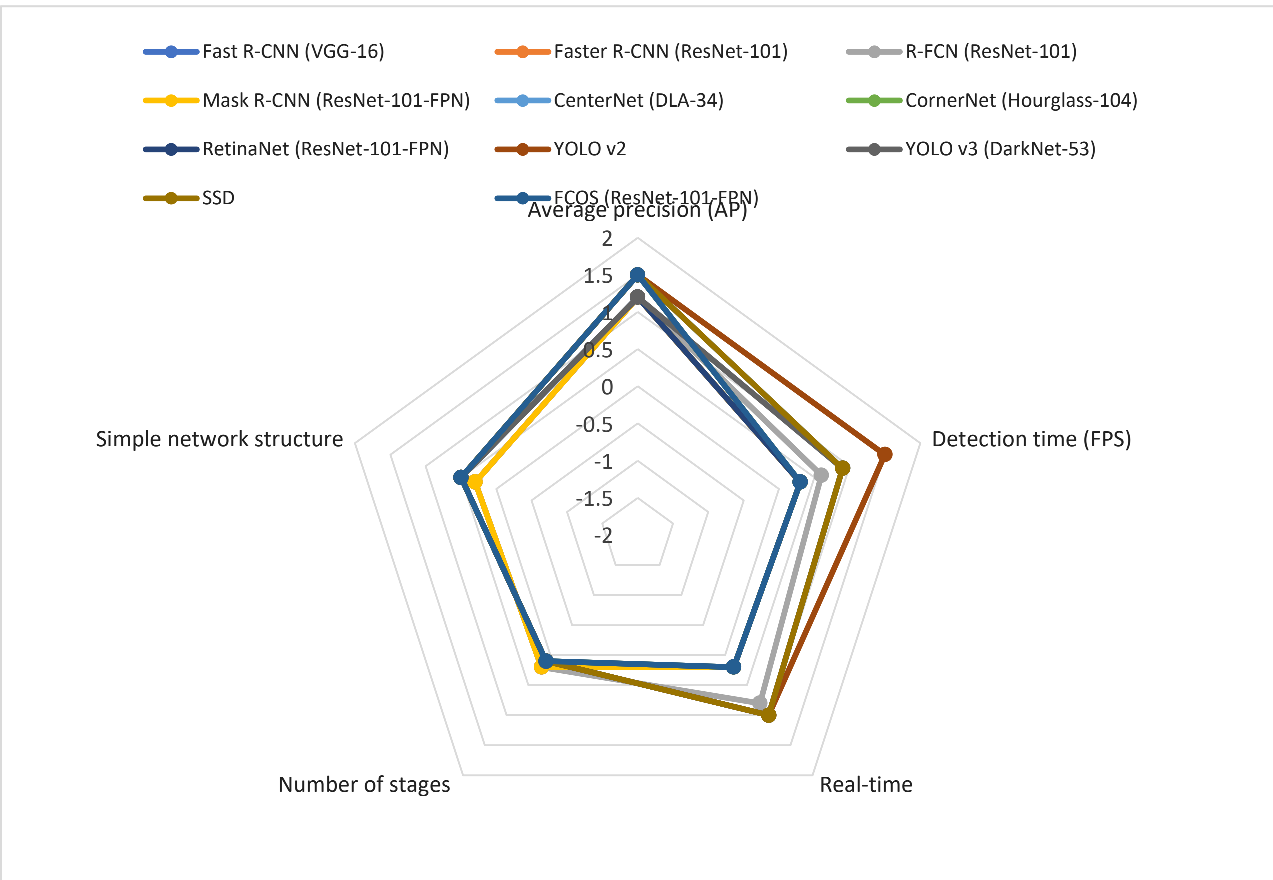

Fig. 5. Spider Chart Multi-Criteria Decision.

The other models CenterNet [8], CornerNet [22], RetinaNet [13], YOLO v3 [32], SSD [6], and FCOS [12] are quite efficient but not as efficient as YOLO v2 in terms of speed (FPS) and accuracy (AP) because these models have sometimes low accuracy and slow speed compared to YOLO v2 so they do not work well in real-time. This result is reflected in the multi-criteria radar graph presented in Fig. 5.

Many works do not consider the use of multi-criteria decision analysis (MCDA) methods which is a valuable tool that can be applied to many complex decisions.

It can solve complex problems that include qualitative and/or quantitative aspects in the decision-making process [33]. In the literature of this field, there is a great lack of this kind of comparison like this article which uses one of the multi-criteria analysis methods such as AHP, WSM, MAUT, and WPM, etc.

VI. Conclusion and Future Work

In this paper, a comparative study based on a weighted scoring model is presented. This study is a comparison of models for object detection in images. This work starts by identifying a set of relevant works that adopt the different models of object detection in images. Then, we described the main architectures of the models that are cited in these works. We have also seen the advantages and disadvantages of the models studied in this article. Thus, we defined the WSM method and then we identified a set of criteria of each model to realize this comparison.

According to the result of our comparison, the best performing model is YOLO v2 because it has high accuracy (AP) and the frame rate per second (FPS) is fast, this means that this model works well in real-time against other models sometimes are slow and they have low accuracy. Based on the Weighted Scoring Model method, the scores of each of the studied models are obtained.

These scores helped us to establish a general classification between these models, but they also showed their strengths and weaknesses concerning each studied criterion.

In future work, we will study the algorithms and models that are effective for the classification of satellite images, and we will try to make an implementation of the most efficient model for the detection and classification of images, especially satellite images. This work provides a contribution to computer scientists and data scientists to help them choose between the different existing models and algorithms, according to their needs and the criteria that matter most to them. The aim of this study is to help the user to make the decision to choose the most efficient model for his project.

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On the Training of Deep Neural Networks for Automatic Arabic-Text Diacritization

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***Abstract*—Automatic Arabic diacritization is one of the most important and challenging problems in Arabic natural language processing (NLP). Recurrent neural networks (RNNs) have proved recently to achieve state-of-the-art results for sequence transcription problems in general, and Arabic diacritization in specific. In this work, we investigate the effect of varying the size of the training corpus on the accuracy of diacritization. We produce a cleaned corpus of approximately 550k sequences extracted from the full dataset of Tashkeela and use subsets of this corpus in our training experiments. Our base model is a deep bidirectional long short-term memory (BiLSTM) RNN that transcribes undiacritized sequences of Arabic letters with fully diacritized sequences. Our experiments show that error rates improve as the size of training corpus increases. Our best performing model achieves average diacritic and word error rates of 1.45% and 3.89%, respectively. When compared with state-of-the-art diacritization systems, we reduce the word error rate by 12% over the best published results.**

Keywords*—Arabic text; automatic diacritization; bidirectional neural network; long short-term memory; natural language processing; recurrent neural networks; sequence transcription

I. Introduction

The Arabic language is vastly spoken and written in many countries around the world. Arabic scripts mainly exist in two forms: Classical Arabic (CA) represented in holy scripts and old books, and Modern Standard Arabic (MSA) which is a contemporary form of CA used nowadays to write stories, books, newspapers, and formal speeches. Moreover, people use dialects that differ from one region to another, to communicate in their everyday lives [1].

Arabic sentences consist of sequences of words, written from right to left, composed of letters and diacritics. Diacritics are generally zero-width characters that appear in the form of marks added above or below the letters. They provide syntactic and semantic distinction that is essential to pronounce and understand Arabic texts [2]. However, diacritics are optional in most texts, especially MSA texts. This causes problems in understanding the text for non-native speakers and children since they may not be able to infer diacritics from the context. Moreover, it poses challenges on automatic Arabic language processing applications which require text to be diacritized such as automatic speech recognition (ASR), text to speech (TTS), and machine translation (MT) [1].

The Arabic language consists of 28 letters and eight basic diacritics. A total of 36 variants of the Arabic letters result from adding the six Hamza letters (ء، آ، أ، ؤ، إ، ئ), the Teh Marbuta (ة), and the Alef Maksura (ى) to the basic 28 letters. These variants have the Unicode hexadecimal codes 0621–063A and 0641–064A. The eight basic Arabic diacritics are: three short vowel diacritics (Fatha, Damma, Kasra), three nunation (Tanween) diacritics, double consonant diacritic (Shadda), and the no-vowel diacritic (Sukun). Arabic diacritics have the Unicode hexadecimal codes 064B–0652. The nunation diacritics are Fathatan, Dammatan, and Kasratan. They can only appear on the last letter of the word. Shadda diacritic is usually combined with either a short vowel or nunation diacritic. With these combined forms, we get a total of thirteen possible different diacritization of a letter in the Arabic language. Table I show the Arabic diacritics along with their transliterated names and list their shapes and sounds when written on the letter Beh (ب).

Diacritics can be classified into two categories: lexemic diacritics and inflectional diacritics. Lexemic diacritics distinguish between words in Arabic morphology that have the same orthography (spelling) but different pronunciations and meanings [3]. Example 1 in Table II shows how adding diacritics to the word كتب in two different ways results in two different pronunciations and meanings. The diacritized word كَتَبَ, pronounced "kataba", is a verb which means "he wrote". The diacritized word كُتُب, pronounced "kutub", is a plural noun which means books. Specifying which diacritization form to use for a word depends on the context.

TABLE I. Arabic Diacritics, their Transliterated Names, and Pronunciations

Diacritic	Transliterated Name	Shape	Sound
Short Vowels	*Fatha*	بَ	/ba/
	Damma	بُ	/bu/
	Kasra	بِ	/bi/
Nunation (Tanween)	*Fathatan*	بً	/ban/
	Dammatan	بٌ	/bun/
	Kasratan	بٍ	/bin/
Double Consonant Diacritic	*Shadda*	بّ	/bb/
No-vowel Diacritic	*Sukun*	بْ	/b/

Example 2 in Table II shows how diacritizing the word كتب using one of the two mentioned forms depends on the context it appears in. More specifically, it differs based on the third word in the sentence. In the first case, it is diacritized as the verb "kataba" since the third word is the noun lesson (الدرس) indicating that this is a verb-subject-object sentence. In the second case, it is diacritized as the noun "kutubu" since the third word is the adjective useful (مفيدة) indicating that this is a nominal sentence. In more complex sentences, diacritizing a word may expand to depend on words even further away in the sentence.

Inflectional diacritics distinguish different inflected forms of the same word. The diacritic of the last letter in the word depends on the position and role of the word in the sentence [3]. Example 1 in Table III shows how placing the noun كُتُب "kutub" in three different positions changes the last letter ب diacritic between Fatha, Damma, and Kasra. The last letter diacritic is often referred to as end case diacritic. Restoring this diacritic is considered a challenging task even when performed manually since it depends on the way the sentence is formed syntactically. Moreover, words (both nouns and verbs) may be inflected by appending suffixes that add features such as voice, number, person, tense, case, and other categorical information [1].

Example 2 in Table III shows how the diacritic of the last letter changes when the verb كَتَب is inflected in three different ways to represent masculine second narration using Fatha in the word كَتَبْتَ, feminine second narration using Kasra in the word كَتَبْتِ, and first narration using Damma in the word كَتَبْتُ. Inflected words make syntactical position of the word affect the diacritization not only of the last letter, but even the letters before. Example 3 in Table III shows the plural noun كُتُبه which is inflected by adding the possessive masculine pronoun ـه. The diacritization of the letter ب which is the letter before the pronoun ـه is the one affected by the position of the word in the sentence.

Consequently, recovering diacritics of undiacritized Arabic text is a challenging yet an important task. Many models have been proposed to automate the process of diacritizing Arabic texts. The performance of these models has been measured using two main metrics that represent the accuracy of the model in providing correct diacritics for the input undiacritized text. These metrics are the diacritics error rate (DER) and word error rate (WER). DER is computed by finding the percentage of wrong diacritics to the total number of characters in the input sequences. WER is computed by finding the percentage of words with at least one wrong diacritic to the total number of words in the input sequences.

TABLE II. EXAMPLES OF LEXEMIC DIACRITICS

Example Number	Forms	Meaning	Pronunciation
1	كَـتَـبَ	he wrote	/kataba/
	كُتُب	Books	/kutub/
2	كَتَبَ أحمد الدرس.	Ahmad wrote the lesson.	
	كُتُبُ أحمد مفيدة.	Ahmad's books are useful.	

TABLE III. EXAMPLES OF INFLECTIONAL DIACRITICS

Example Number	Forms	Meaning	Pronunciation
1	كُتُبُ أحمدَ مفيدة.	Ahmad's books are useful.	/kutubu/
	قرأتُ كُتُبَ أحمدَ جميعها.	I read all Ahmad's books.	/kutuba/
	أعجبت بكُتُبِ أحمدَ جميعها.	I liked Ahmad's books.	/kutubi/
2	كَتَبْتَ	You wrote (masculine)	/katabta/
	كَتَبْتِ	You wrote (feminine)	/katabti/
	كَتَبْتُ	I wrote	/katabtu/
3	كُتُبُهُ مفيدة.	His books are useful.	/kutubuhu/
	قرأ أحمد كُتُبَهُ.	Ahmad read his books.	/kutubahu/
	اعتنى أحمد بكُتُبِهِ.	Ahmad took care of his books.	/kutubihi/

Although the best previous solutions have shown steady improvement in accuracy over time, we think that the latest accuracies can be improved further using better models and training datasets. In most cases, the accuracy is restricted due to the lack of large, cleaned training dataset with acceptable diacritization to character rate. In this work, we extend the cleaning process performed in [4] to include the entire Tashkeela dataset. We concentrate on finding the effect of the training dataset size on the diacritization accuracy and on reducing the error rates through using larger datasets. Finding the effect of the dataset size on model accuracy and the best training size would hopefully help interested researchers to reach even better accuracies. The cleaning process was performed in steps such that eight corpora are extracted and cleaned with incremental sizes in terms of number of sequences. We perform experiments that use these corpora to explore and analyze the effect of increasing the training dataset size on the accuracy of our baseline model.

We build on our previous experience in designing a model that exploits the efficiency of bidirectional long short-term memory (BiLSTM) recurrent neural networks in automatic diacritization of Arabic texts. These networks are characterized with their ability to utilize long-term past and future contexts to predict diacritics. Our work produces a cleaned dataset of 543,364 sequences with diacritization to character rate of at least 80%. This dataset can be used to experiment training more sophisticated diacritization models. Moreover, our best-performing BiLSTM model achieves DER of 1.45% and WER of 3.89%.

The rest of this paper is organized as follows. The next section reviews systems proposed to automate the diacritization of Arabic text. Section III provides background information of sequence transcription and recurrent neural networks. Section IV illustrates our experimental setup. Section V presents and discusses the results of our experiments and compares our best results with the results of previous best performing models. Finally, we conclude our work in Section VI.

II. Literature Review

Diacritization is the process of adding diacritics to the letters of undiacritized texts. This operation is essential to many applications that involve translation and text-to-speech (TTS) conversion. Many models have been proposed over the years to automate the process of diacritizing Arabic text. These models involve rule-based models, statistical models, and hybrid models. Rule-based natural language processing (NLP) systems depend on using a set of well-defined language-dependent rules which are formed by exploiting solid linguistic knowledge. These systems are based on dictionaries and/or morphological and syntactic analyzers/generators [5][6]. Although rule-based approaches achieve acceptable results, their main drawback is the difficulty of maintaining and including all aspects of the language in a comprehensive set of rules. This is even more significant with a complex language morphologically and syntactically like the Arabic language [7].

Statistical approaches use large corpora of diacritized texts to predict the probability distribution of diacritics for a sequence of characters. The main advantage of these approaches is that they do not depend on a set of rules to solve the problem and hence do not require solid linguistic knowledge. Statistical methods that have been applied to Arabic text diacritization include hidden Markov models (HMM) [8][9], n-grams [10], finite state transducers (FST) [11], conditional random fields (CRF) [12], and neural networks. Recently, most proposed systems combined statistical approaches with linguistic knowledge such that the stochastic process is guided by language specific rules, introducing hybrid approaches [3, 13-19].

More recently, RNNs have been successfully used to solve restoring diacritics of Arabic texts as a sequence transcription problem. Our previous work in [20] proposed, trained, and tested a bidirectional LSTM network that transcribes raw undiacritized Arabic sequences with fully diacritized ones. Error correction techniques were used as a post processing step to the output of the network to overcome some transcription errors. We also experimented preprocessing the RNN input using a morphological and syntactical analyzer in [21]. Mubarak et al. [22] implemented a sequence-to-sequence model using an encoder-decoder LSTM RNN with content-based attention. They used a fixed length sliding window of character-based n-words in the training process and a voting algorithm of n-gram probabilistic estimation to select the most likely diacritic form of a word. They trained their model using 4.5 million tokens and tested it using the freely available WikiNews corpus of 18,300 words.

In [4], Fadel et al. tested and compared a few existing web-based automatic diacritization tools. They produced a cleaned subset of 55K sequences from the Tashkeela dataset which is split into training, testing, and validation sets. In [23], they implemented and tested several neural network models that belong to two main approaches, feed forward neural networks and recurrent neural networks. They explored several models using different types of input layers, using a CRF classifier instead of the softmax layer, and optimizing gradients normalization using block-normalized gradient (BNG).

Darwish et al. [24] proposed an approach to automatic diacritization that consists of two bidirectional LSTM RNNs. The first network is responsible for core-word (i.e., all letters other than the last letter of the word) diacritics and the second is responsible for case-ending (i.e., last letter) diacritics. They trained and tested their approach on two sets: one that represents MSA texts and the other represents CA texts. Their model included post correction using a unigram language model.

In our most recent work [25], we trained and tested RNN models using two datasets: Linguistic Data Consortium's Arabic Treebank part 3 (LDC-ATB3) [26], and the cleaned subset of Tashkeela [4]. We performed extensive experiments to explore and analyze the effect of tuning several network parameters, such as the number of network layers and using dropout, on the accuracy and execution time of the tested models. We also experimented models built using different network architectures, alternative approaches to handle problems in sequence lengths, and multiple encoding methods for the diacritized output sequences.

Madhfar and Qamar [27] implemented and experimented automatic diacritization using three character-level deep learning models. The first model is a network that consists of six layers: an embedding layer, followed by three bidirectional LSTM layers, a projection layer, and finally, a softmax layer. The second model consists of an encoder and decoder with location-based attention. The third model consists only of the encoder part of the second model. Its core architecture is implemented using a 1-D convolution bank, a multi-layer highway network, and a bidirectional GRU network. The model is named CBHG (1-D Convolution Bank + Highway network + Bidirectional GRU).

In this paper, we experiment training a deep BiLSTM model using several datasets with incremental sizes extracted from the Tashkeela dataset. Our goal is to test the accuracy of the trained model in each case, thus investigating the effect of the training set size on the accuracy of diacritization. Moreover, our work includes extracting a cleaned corpus of the full dataset of Taskeela which includes only sequences with diacritization to letter rates greater than 80%.

III. Sequence Transcription

Many machine learning tasks can be implemented as a sequence transcription problem, in which input sequences are translated into corresponding output sequences. These include speech recognition, machine translation, and text to speech [28]. Arabic text diacritization has been expressed successfully as a sequence transcription problem as well [20-27]. In our work, an input sequence X consists of characters $x_1, x_2, x_3, \dots, x_T$ that represent the undiacritized sequence. The output sequence Y is a sequence of diacritics $y_1, y_2, y_3, \dots, y_T$ such that y_i is the diacritic of the letter x_i.

Recurrent neural networks (RNNs) have proved to perform best on sequence transcription problems. This is because cells' hidden states are functions of all previous states with respect to time. This provides RNNs with their ability to maintain correlations between data points in the input sequence and the capability of pointing backward in time [28]. Basic recurrent neural networks are generalization of feedforward neural networks to sequences [29]. Given a sequence of inputs $(x_1, x_2, \ldots, x_T)$, a standard RNN computes a sequence of outputs $(y_1, y_2, \ldots, y_T)$. At each time step, a recurrent neuron receives the output vector from the previous time step $y_{i(t-1)}$, in addition to the input vector $x_{i(t)}$. Hence, $y_{i(t)}$ is a function of $x_{i(t)}$ and $y_{i(t-1)}$, which is a function of $x_{i(t-1)}$ and $y_{i(t-2)}$, which is a function of $x_{i(t-2)}$ and $y_{i(t-3)}$, and so on. Consequently, $y_{i(t)}$ is a function of all input vectors since $t = 1$ [30].

Sequence transcription problems solved using RNNs can be classified into four categories based on the lengths of input and output sequences [30]. One-to-one networks take an input sequences and produces an output sequence of the same length. Sequence-to-vector networks transcribe input sequences into one final output by ignoring all previous outputs. Vector-to-sequence networks take one input vector and produce an output sequence. The general sequence-to-sequence network has output sequence that is generally not of the same length as the input sequence. This type is often implemented using the encoder-decoder architecture [31]. In this work, we implement automatic Arabic diacritization as a one-to-one sequence transcription problem since for each input sequence of characters; the output sequence of diacritics is of the same length.

Long short-term memory (LSTM) RNNs were first proposed in [32] to deal with the basic RNNs' problem of decaying or slowly changing weights. This results in their disability to learn long dependencies in the input sequences. LSTM networks, on the other hand, which use purpose-built memory cells, can converge faster, and detect long-term dependencies in the sequences [28]. Each memory cell has two states, the short-term state (also used as the cell output) $h_{(t)}$ and a long-term state $c_{(t)}$. These states are updated using an input gate, a forget gate, an output gate, and a cell activation unit. The operation of these gates collectively enables the LSTM cell to capture long term patterns by recognizing important inputs, preserving them as long as they are needed, and extracting them whenever they are needed. Fig. 1 shows a basic RNN cell and an LSTM cell.

Conventional unidirectional RNNs can make use only of previous context. However, many sequence transcription problems, including diacritization, require exploiting future context as well. Bidirectional RNN layers achieve this by comprising two unidirectional layers that process the sequence in both time directions producing two hidden vectors. The output is a function of both vectors and, consequently, exploits past and future contexts [33]. Fig. 2 shows the general structure of the bidirectional neural network unfolded for three time-steps. RNNs are made even more powerful by stacking multiple layers on top of each other forming a deep RNN. Deep networks are necessary to solve complex transcription functions. In such architectures, the output sequence of one-layer acts as the input sequence for the next layer.

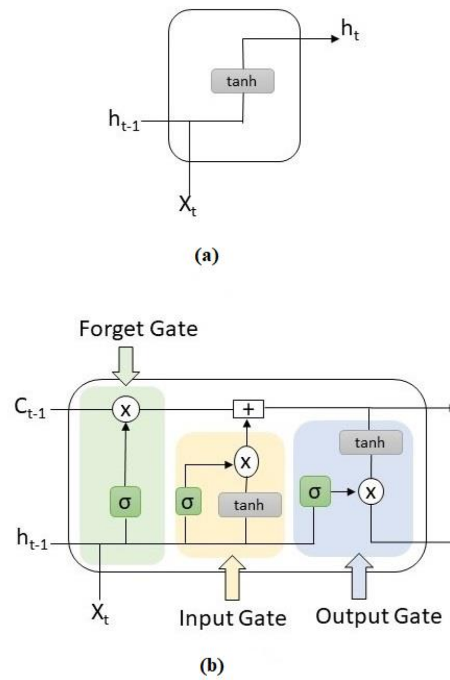

Fig. 1. (a) Basic RNN Cell, (b) LSTM Cell.

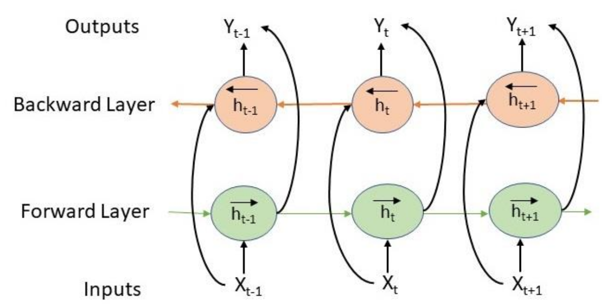

Fig. 2. General Structure of the Bidirectional Neural Network Shown unfolded for Three Time Step.

IV. Experimental Setup

In this section we provide the details of the experiments conducted in this work. We illustrate the methodology used, how datasets were extracted and preprocessed, the scheme used to encode sequences, and the structure of our baseline model. We performed all experiments on the Cyclone supercomputer of the High-Performance Computing Facility of The Cyprus Institute [34]. The processing and memory specifications of the used resources on the platform are listed in Table IV.

TABLE IV. Processing and Memory Specifications of the Experimental Platform

CPU	Intel Xeon Gold 6284 @ 2.5 GHz, 20 cores (40 threads), 27.5 MB cache
GPU	Nvidia Tesla V100-SXM2 @ 1.53 GHz, 5120 CUDA cores, 32 GB memory
Memory	192 GB DDR4-SDRAM

A. Methodology

We performed several experiments which involved training of our baseline model using corpora with different sizes. All experiments went through two phases: the first phase is training the model and the second phase is testing its diacritization accuracy. In the training phase, diacritics are removed from diacritized training sequences to generate undiacritized sequences. Generated undiacritized sequences represent the model input sequences whereas diacritic sequences are the model target sequences. Both undiacritized input sequences and diacritic target sequences are fed to the model after being encoded. Fig. 3 shows the steps performed in the training phase of the performed experiments.

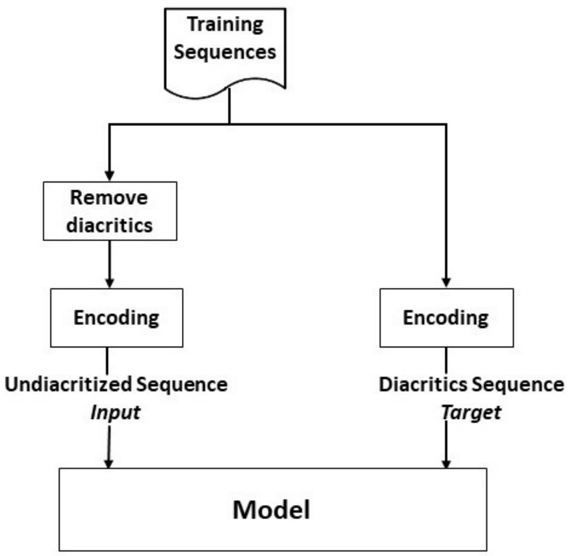

Fig. 3. Training Phase of Experiments.

In the testing phase, diacritics are removed from diacritized testing sequences. The trained model takes the generated undiacritized sequences as input to predict their diacritics. We perform minor corrections to the output sequences according to rules developed in our previous work in [20]. Corrected output sequences are stored in a text file named diacritized_output.txt. We test the accuracy of the model by comparing the model diacritized sequences, in the file diacritized_output.txt, with the correctly-diacritized target sequences, stored in a file named target_output.txt, in measures of DER and WER rates. Fig. 4 shows the steps performed in the testing phase of the performed experiments.

B. Training Datasets

The Tashkeela dataset [35] consists of 75 million diacritized words. In its main part, it is collected from 97 books filtered from 7079 books of Shamela library which is an Islamic electronic library. These books are example of CA text. Only 1.15% of the Tashkeela dataset consists of MSA texts which is drawn from modern books and crawled from the Internet. This makes Tashkeela mainly an example of CA. In [4], Fadel *et al.* extracted a subset of 55,000 sequences from the Tashkeela dataset with diacritization to character rate of at least 80%. The subset was cleaned by removing English letters and extra whitespaces, fixing some diacritization issues, and separating numbers from words, among other techniques. The subset was divided into 50,000 sequences for training, 2,500 sequences for validation, and 2,500 sequences for testing. This subset was used in our previous work in [25] to train and test the developed model.

In this work, we use the cleaning and filtering scripts developed by Fadel *et al.* [4] to extract the larger datasets used in our experiments. In addition, we wrap sequences such that they have maximum lengths of 400 characters. This step is performed to reduce the training time and memory usage and is based on experiments we conducted in our previous work [25]. One of the main goals of this work is to study the effect of incrementing the training data size on the diacritization accuracy. We use the 50k training sequences of Fadel et al. as a base dataset from which smaller training sets are derived and larger training sets are formed by adding more sequences to it. Three smaller subsets are derived by randomly selecting 6,250, 12,500, and 25,000 sequences from the basic dataset. Since the basic dataset is cleaned and filtered to meet the diacritization to character rate of 80%, except for wrapping to 400-character length, no further work was needed for these subsets.

In order to construct larger datasets, we randomly select sequences from the Tashkeela corpora to be added to enlarge our sets, starting with the 50K set. The sequences are selected to have at least 80% diacritics to characters rate. Then, they are processed using the cleaning scripts. To avoid duplication of sequences in our sets, the selected sequences are checked not to be already included in the set to be enlarged. Finally, we wrap sequences lengths to 400 characters. By repeating this process, we extracted datasets that consist of 100,000, 200,000, and 400,000 sequences. We also obtain the largest set used in our experiments which results from including all available sequences from Tashkeela that satisfy the above criterion, which is 543,364 sequences.

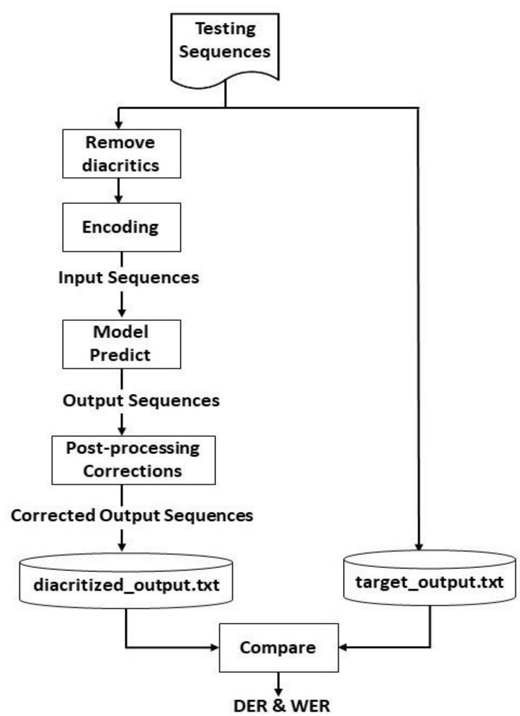

Fig. 4. Testing Phase of Experiments.

Except for the largest dataset, the sizes of the datasets are incremented by doubling the number of sequences from one set to the next. Moreover, the incremental process by which a new set is formed by adding sequences to the current set maintains the inclusion property, such that each dataset is a subset of the next. Table V shows size statistics of the used datasets in terms of word count, letters per word, words per sequence, and the number of sequences after the dataset is wrapped. All used subsets have close letters per word and words per sequence rates. For all experiments, we use the same validation set of 2,500 sequences, and testing set of 2,500 sequences to test the DER and WER of the trained model in each experiment.

TABLE V. SIZE STATISTICS OF THE EXTRACTED DATASETS

Dataset Size (# of sequences)	Word Count	Letters per Word	Words per Sequence	# of Sequences after Wrapping
6,250	259,847	3.98	41.5	7,675
12,500	522,502	3.97	41.7	15,334
25,000	1,059,573	3.97	42.4	30,847
50,000	2,103,071	3.97	42.1	61,453
100,000	4,180,191	3.97	41.8	122,817
200,000	8,410,559	3.97	42.1	245,994
400,000	16,854,689	3.97	42.1	492,288
543,364	22,729,365	3.97	41.8	667,990

C. Data Encoding

Sequences used in our experiments are either undiacritized consisting of letters only, or diacritized consisting of both letters and their diacritics. Undiacritized sequences are encoded using the Unicode representations of their letters. For diacritized sequences, we experimented using different encoding schemes in our previous work [25]. A one-to-one encoding scheme which represents each diacritic produced the best results in all performed experiments. Hence, we use this encoding scheme in this work. This scheme benefits from the fact that letters must not change between the input and the output sequences. Only diacritics must be added. Hence, it limits the classes at the output to the number of possible diacritics codes which is 16. Table VI shows the binary codes used for the eight Arabic diacritics. In Arabic, a letter may have two diacritics if one of them is *Shadda*. In this case, the diacritic code is formed by ORing the *Shadda* code (1000) with the other diacritic code. Fig. 5 shows an example of encoding the diacritized word صَيَّادٌ (hunter) which includes letters with no, one, and two diacritics.

D. Base Model

For building our models, we use Keras (Python deep learning library) with TensorFlow at the backend [36]. Our baseline model is an BiLSTM that consists of an embedding layer of 32 dimensions, four bidirectional LSTM layers each consisting of 256 cells, followed by a 16-cell fully-connected output layer. The Softmax function is used for activating the diacritic class with the highest probability at the output layer. Adam optimizer is used in training, and the sparse categorical cross entropy is used as the loss function. The batch size is set to 128 sequences for all experiments. In addition, the maximum number of epochs used in training is 100 with early stopping such that training stops if the validation accuracy does not improve for five consecutive epochs. Fig. 6 shows the structure of our baseline model.

TABLE VI. BINARY BIT CODES USED TO ENCODE DIACRITICS IN OUR EXPERIMENTS

Diacritic	Bit Code
No diacritic	0000
Fathatan (◌ً)	0001
Dammatan (◌ٌ)	0010
Kasratan (◌ٍ)	0011
Fatha (◌َ)	0100
Damma (◌ُ)	0101
Kasra (◌ِ)	0110
Sukun (◌ْ)	0111
Shadda (◌ّ)	1000

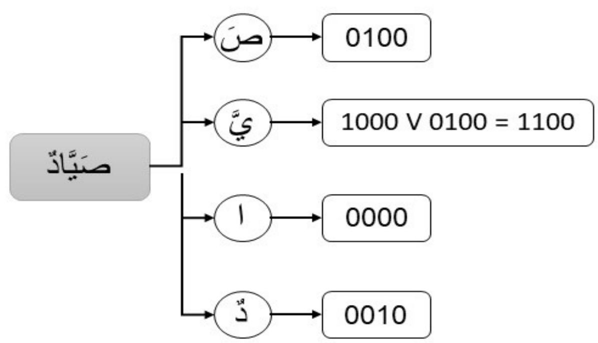

Fig. 5. Example Encoding the Diacritized Word صَيَّادٌ (Hunter).

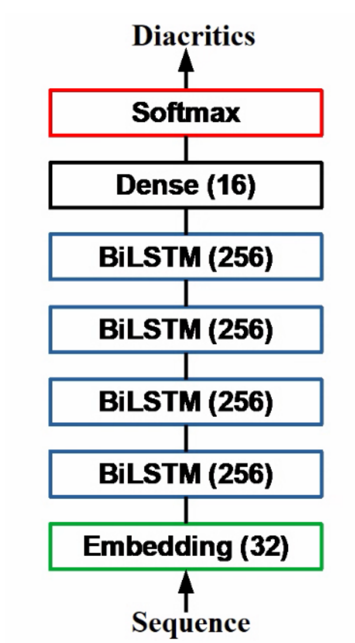

Fig. 6. The Structure of the base Model used in our Experiments.

V. Experiments and Results

The following subsections present the experiments performed and discuss their results. We also compare our best results with previous work.

A. Experiments

We experimented training our baseline model using the eight corpora we extracted from the Tashkeela dataset. We evaluated the trained model in each experiment in terms of time required to train the model and the model accuracy. We report the training time both in terms of the training total execution time and the average training time per epoch for each of the eight experiments. Table VII shows the total training time, average execution time per epoch, and number of executed epochs for each of the eight experiments. As expected, larger corpus size results in longer training time. However, the increase in the execution time is not directly proportional to the increase in number of sequences. This is dependent on the number of epochs which vary from one experiment to another based on when the early stop occurs. On the other hand, it can be observed that the increase in average time per epoch is proportional to the corpus size.

We report the performance of the models during training using the validation set in terms of validation loss and validation accuracy. Fig. 7 shows the validation accuracy and Fig. 8 shows the validation loss as functions of the training epochs for each experiment. In all reported results, we refer to each experiment by the number of sequences of its training dataset (i.e., 6,250, 12,500, 25,000, …). Training using larger number of sequences generally results in slower learning, higher values of accuracy and lower loss values. The best validation accuracy and validation loss achieved are 0.988 and 0.016, respectively, using the largest dataset of 543,364 sequences.

We tested the diacritization accuracy of the trained models using the eight extracted corpora. For all testing experiments, we use the test set of 2,500 sequences defined by Fadel *et al.* [4]. Fig. 9 shows diacritization error rates and word error rates for the eight models. The results show that both DER and WER improves as the number of sequences used in training increases. The best improvement, which is 22%, is observed when the training set increases from 6,250 sequences to 12,500. The improvement decreases gradually as we move towards larger datasets. No improvement is observed in the error rates when increasing the training set from 400,000 to 543,364 sequences. The best DER and WER achieved are 1.45% and 3.89%, respectively.

TABLE VII. Total Training Time, Average Execution Time Per Epoch, and Number of Executed Epochs for the Eight Experiments

Dataset Size (# of sequences)	Total Training Time (hours)	Epoch Average Training Time (hours)	# of Epochs
6,250	5.1	0.05	100
12,500	9.2	0.09	88
25,000	10.6	0.18	58
50,000	21.4	0.36	60
100,000	32.1	0.63	51
200,000	56.3	1.22	46
400,000	191.0	2.27	85
543,364	336.0	3.43	98

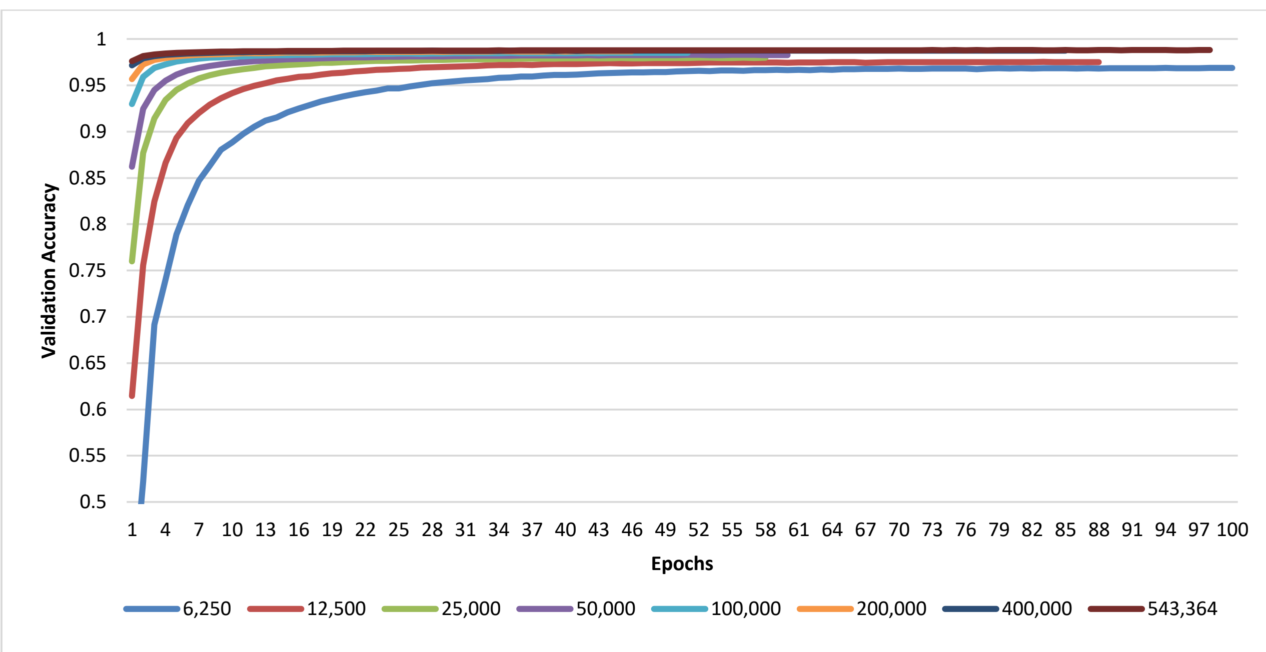

Fig. 7. Validation Accuracy Recorded during Training the Model using Datasets with different Number of Sequences.

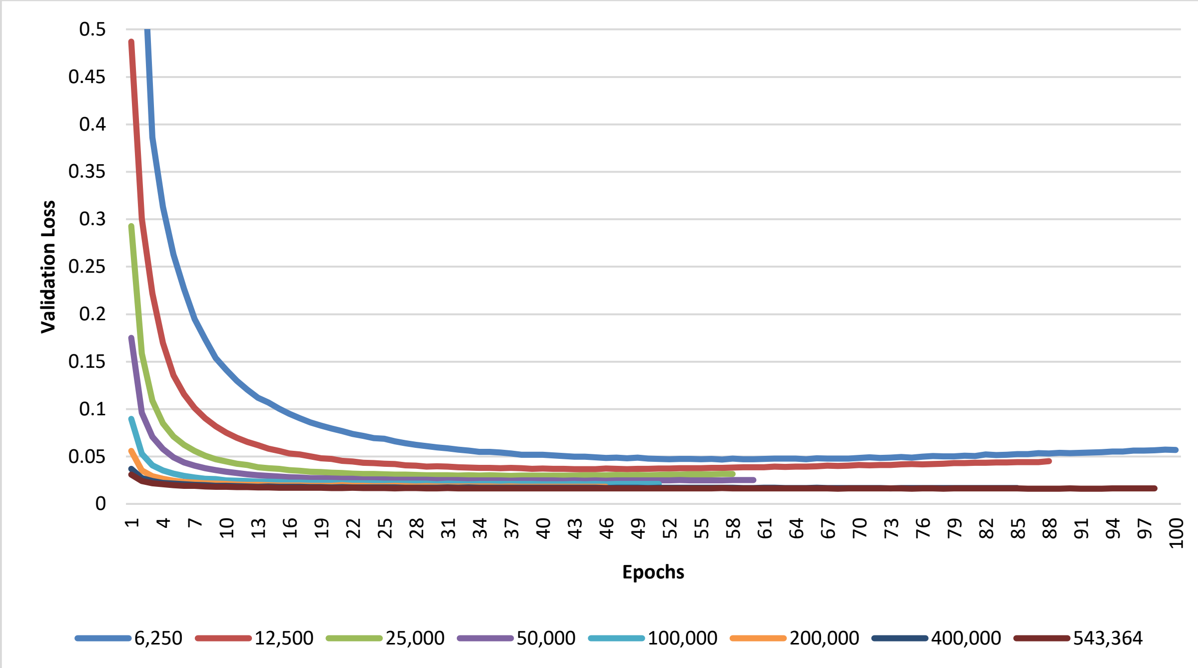

Fig. 8. Validation Loss Recorded during Training the Model using Datasets with different Number of Sequences.

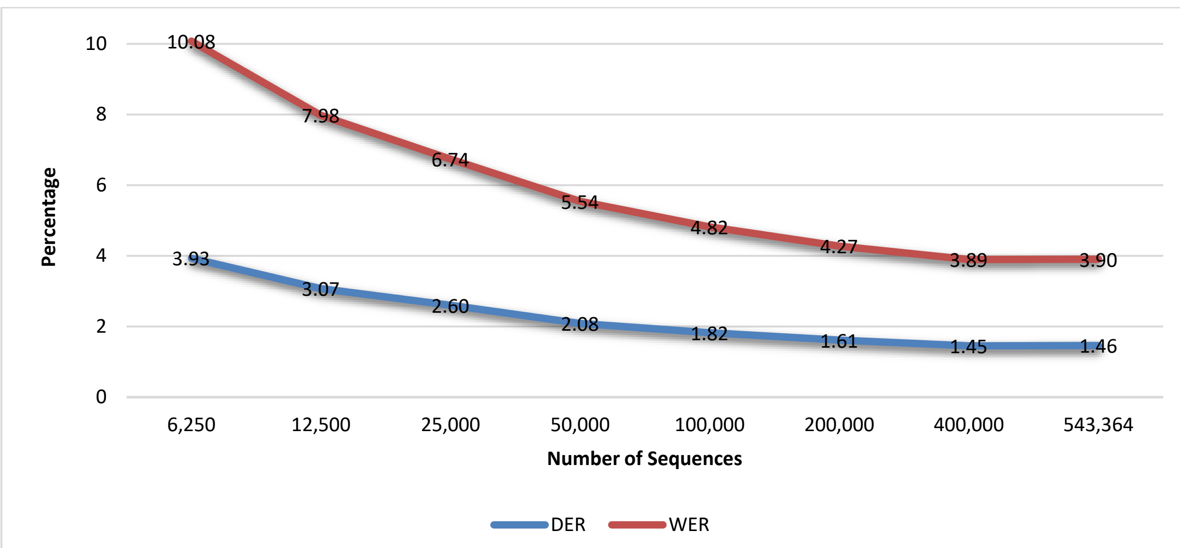

Fig. 9. DER and WER Values for Models Trained with different Number of Sequences.

We analyze errors of our system by enumerating the errors according to the number of errors per word and presence of end-case diacritization errors. The results of this analysis are shown in Fig. 10 and 11. Fig. 10 shows that for all dataset sizes, most of the miss-diacritized words have one diacritic error. Words with three or more diacritic errors are not frequent contributing to less than 6% of the errors in all experiments. Moreover, the ratio of multiple errors per one word decreases with larger datasets. Fig. 11 shows the end-case diacritization errors contribution in the DER and WER ratios. As explained earlier, end-case diacritization depends on the context and is subject to complex inflection rules. In our results, end-case diacritization errors contribute to about half of the word errors in all experiments. The best DER and WER values when ignoring end-case diacritization errors are 0.91 and 1.95, respectively.

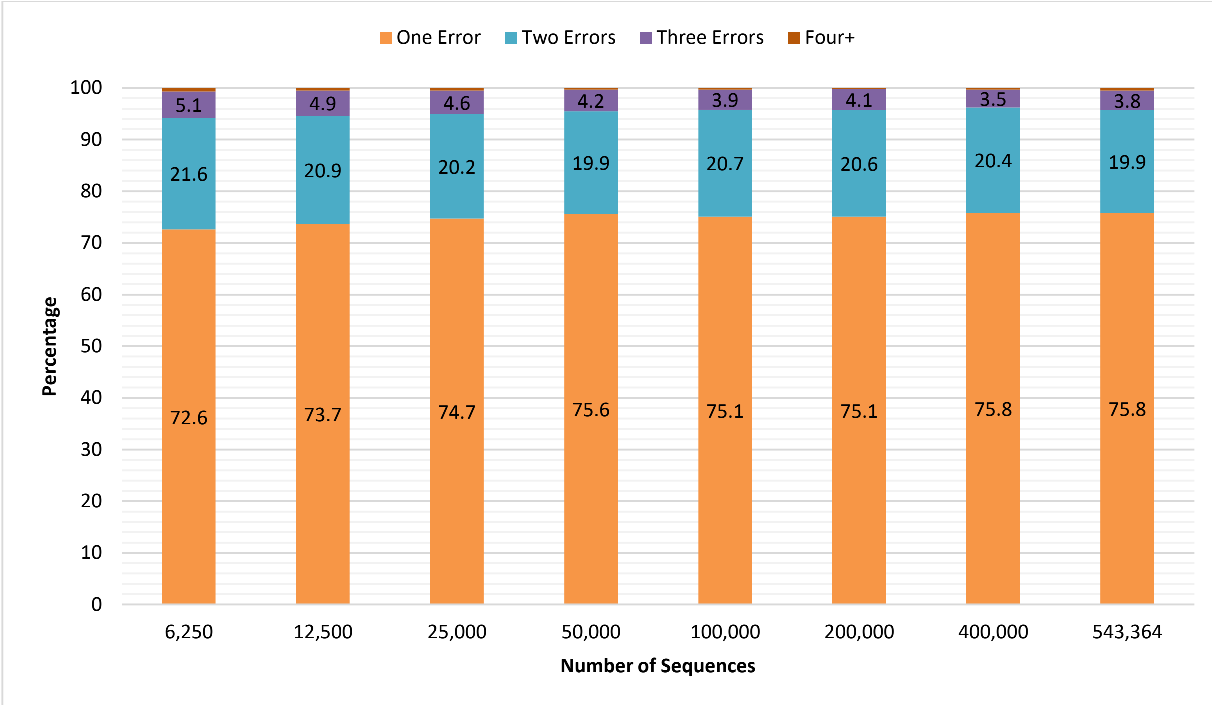

Fig. 10. Number of Errors per Word for each Experiment as a Percentage of the Total Number of Errors.

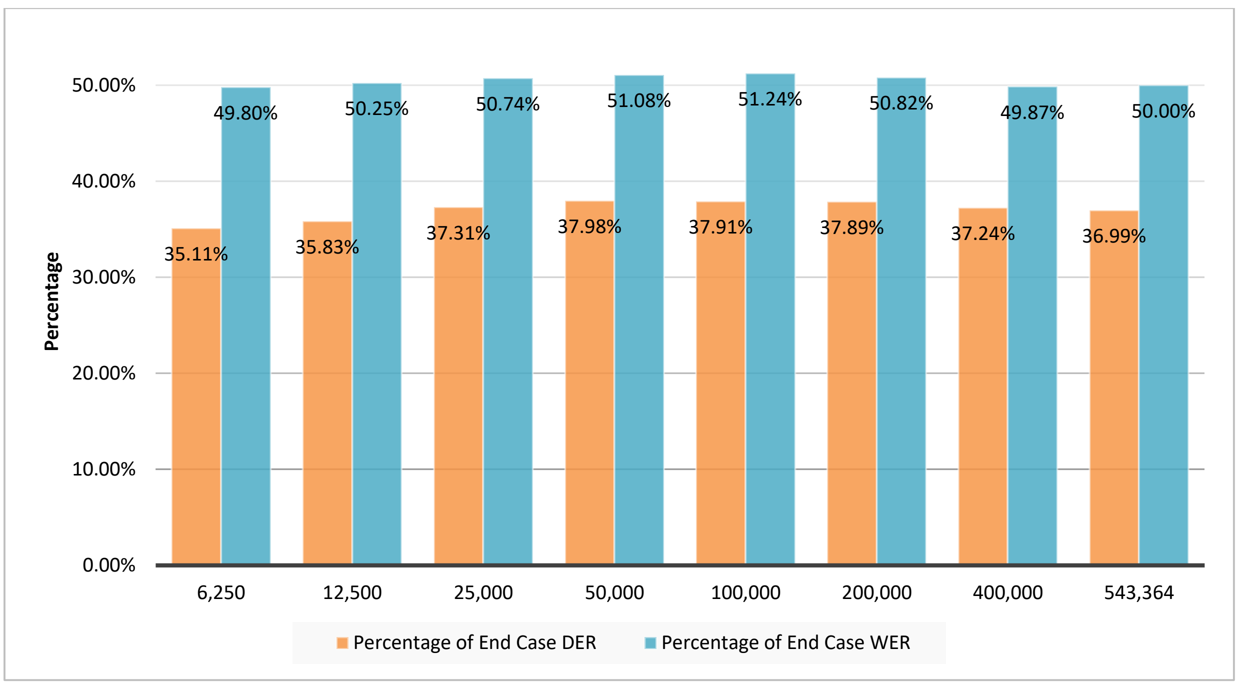

Fig. 11. Contribution of the End-case Diacritization Errors in the DER and WER Ratios.

B. *Comparison with Previous Work*

Our best results are reported here are for the model trained using 400,000 sequences. Table VIII summarizes the comparison of the best results in this work and best published systems. For each system, the table shows its publication year, the database used in evaluating it, and its DER and WER values both when including all diacritics errors (i.e., with case ending) and when ignoring last-letter diacritization errors (i.e., without case ending). The last column shows DER resulting from last letter diacritization errors only.

TABLE VIII. COMPARISON OF OUR BEST DER AND WER RESULTS WITH PREVIOUS WORK

System	***Dataset***	***All Diacritics***		***Ignore Last***		***DER Last***
		DER	***WER***	***DER***	***WER***	
Zitouni *et al.* (2006) [15]	ATB3	5.5	18	2.5	7.9	3.0
Habash&Rambow (2007) [3]	ATB3	4.8	14.9	2.2	5.5	2.6
Rashwan *et al.* (2011) [17]	ATB3	3.8	12.5	1.2	3.1	2.6
Said *et al.* (2013) [18]	ATB3	3.6	11.4	1.6	4.4	2.0
Fadel *et al*. (2019) [23]	Tashkeela	2.18	4.44	1.76	2.66	0.42
Abandah *et al.* (2020) [25]	ATB3	2.46	8.12	1.24	3.81	1.22
	Tashkeela	1.97	5.13	1.22	3.13	0.75
Madhfar and Qamar (2021) [26]	Tashkeela	1.13	4.43	0.84	2.47	0.29
This work	**Tashkeela**	**1.45**	**3.89**	**0.91**	**1.95**	**0.54**

Most previous work used either LDC's Arabic Treebank Part 3 (ATB3) [26], which represent an example of MSA, or Tashkeela, which represents an example of CA, or both. To the best of our knowledge, our previous work in [25] achieves the best published results for ATB3. The size of the ATB3 dataset is limited to 22,170 training sequences, which makes it unsuitable for the experiments we perform in this work. We do not include the results of Darwish et al. [14] since they use different training and testing datasets in both their MSA and CA experiments and hence comparison would not be fair. They used the training dataset of the RDI diacritizer in [18] and a test set of WikiNews for their MSA experiments. For their CA experiments, they used data from an undefined publisher.

The best DER and WER achieved in this work are 1.45% and 3.89%, respectively. This improves over our previous work which used a subset of the Tashkeela dataset and reported a DER of 1.97% and a WER of 5.13%. We compare our results with the best results of Fadel *et al.* [23] and Madhfar and Qamar [26] since both works use the Tashkeela dataset for training and testing. We outperform the model developed by Fadel *et al.* in DER and WER both with and without case ending. However, they achieve better last letter diacritization error rate.

Among the models they experimented, Madhfar and Qamar report the best DER and WER values for their CBHG model. In our comparison, the CBHG model of Madhfar and Qamar achieves the best DER in all cases. However, our best-performing model word error rates outperform those of the CBHG model indicating that our model results in less percentage of wrongly diacritized words. Noting that they perform their own cleaning and filtering process, but with different rules, to extract datasets used in training their models. It's worth mentioning that our best-performing model outperforms the baseline model of Madhfar and Qamar, which is a deep BiLSTM RNN. DER and WER values reported for their baseline model are 2.24% and 8.74%, respectively.

It can be observed that our base model achieves results that are comparative to more complex models such as the CBHG model proposed by Madhfar and Qamar. This shows that training using a large clean dataset with high diacritization to letter rate provides competitive diacritization accuracy. Training more-sophisticated models using such a dataset would certainly provide even better results. Although this work involves experimentations using a basic BiLSTM RNN, it generates cleaned corpora with incremental sizes that can be used to experiment with several other models. Moreover, it shows that state-of-the-art error rates could be achieved when training using large clean corpora.

VI. CONCLUSION

Automating diacritization of Arabic texts is a crucial operation for many Arabic NLP applications. In this paper, we have conducted several experiments to study the effect of changing the training data size on performance. Our work included generating several cleaned subsets of the Tashkeela corpora with incremental size in terms of number of sequences. Our largest subset, which consists of 543,364 sequences, can be used for training other models and comparing them, such as the model used by Madhfar and Qamar [26]. Our baseline model is a deep LSTM bidirectional RNN. We evaluated the performance of our baseline model during training using each of the generated corpora by monitoring the validation loss and accuracy using the validation set. We tested the diacritization accuracy of the model after being trained using each corpus by finding its DER and WER values when diacritizing the 2,500-sequence testing set.

Our experiments indicate that performance of the trained model improves as training set size increases. However, improvement in DER and WER values decreases as the number of sequences increases. Best achieved DER and WER values are 1.45% and 3.89%, respectively, using a training dataset size of 400,000 sequences (about 17 million words). Our WER value is the best when compared with other state-of-the-art results. In order to further improve the performance, we aim to experiment with other proposed models and to develop a loss function that considers unharmful differences between the output and target sequences when training is performed.

ACKNOWLEDGMENT

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Unsupervised Clustering of Comments Written in Albanian Language

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***Abstract*—Now-a-days, social media and communications in social media have become very important for services providers and those play a key role in service quality improvement as well as in decision making. The services consumers' discussions usually are written in their local languages and extracting important knowledge sometimes is very hard and problematic. In this field the natural language processing techniques are helpful, but different languages have their specifics and difficulties, and some languages are not prosperous enough in the techniques and methods on NLP, especially the local speaking of the language. In this scientific paper, we have tried to solve such a problem for the Albanian language spoken in Kosovo. Namely, for a dataset of the comments, written in Albanian language in Kosovo (local speaking), collected from the social media, by use of unsupervised clustering techniques, to make clustering regarding the topic of discussion in the comment. In this research, the different techniques of text feature extraction (vectorization and others) and clustering algorithms (K-means, Spectral, Agglomerative, etc.), are used with the idea to find and define more appropriate techniques for the Albanian language. In this paper are shown the results of the conducted experiments as well as discussions about what to use in case of the Albanian language and other languages similar or in group with Albanian (those which have a weak NLP).**

Keywords*—Unsupervised clustering; k-means; spectral; agglomerative; vectorization; Albanian language

I. Introduction

Data flow nowadays is produced in various industries and fields using technology and this is a challenge in itself which requires management in concrete form. Except for electronic sources such as websites and communication forms by using other mediums. So, social networks are one of the main factors that continue to allow all users to produce different information. At the same time, trends show that different companies tend to use these comments/ sentiment by creating a profile for each user in order to suggest their products according to users' activity. This process, as a whole, requires data management which we otherwise call big data. So, most of the social networks that exist and are used in the world have taken the role of big data producer [1] [2] [3].

This paper mainly examines the use of unsupervised clustering algorithms on social media comments written in Albanian language. Furthermore, this paper demonstrates the text analysis process in reviewing the public opinion of services of Vala Telecommunication Company towards a certain brand and presents hidden knowledge (e.g. services, quality and challenges during operation of their services) that can be used for decision making after the text analysis is performed. Through this paper, we will be focused on implementation of several unsupervised clustering algorithms which they have a wide range field implementation even in different field such as [4], [5], [6], where the main purpose is to identify and create clusters by classifying collected data and distinguishing them as content from extracting and presenting concrete results from processed data through different algorithms. According to Smita Agrawal et al. [2], clustering analysis try to identify the groups of objects such that it forms the groups of similar or related objects groups and in difference forms they are not related to the objects in other groups. Also, Alrence Santiago Halibas et al. [7], shows classification by using similarity by using techniques on English language, the same such in our case we used on Albanian language and as content have classification and clustering of extracted data from social network Twitter. Also, they have used preprocessing techniques preparing data in order to display the visualization of the dataset used.

This paper is organized as follows: Section II is a short literature review regarding the topic, then section III the research methodology used. Implementation of several unsupervised clustering algorithms is shown in Section IV. And, finally, the conclusions and findings in Section V.

II. Literature Review

In this section, we briefly introduce the related technologies involved in our algorithms, including preprocessing phases and visualization of gained results, which are widely used by unsupervised clustering. Our proposed implementation form of clustering of sentiment written on Albanian language is based on the improvement of these three algorithms, which will be described in detail in Section IV.

So, extracting semantic relations has been successfully applied and shown in this part. As found in, Alrence Santiago Halibas et al. [7], use K-Means algorithms where it determines the set of *k* clusters and assigns each example to a specific cluster. This is applied by using sentiment of business analytics on Twitter social network. It has been extracted from the dataset by using preprocessing procedures and visualizing the results of the dataset.

Another researcher, Juan Antonio Lossio-Ventura et al. [8], have used the same social network where they used health-related models and document clustering applications on a Twitter composed of two subsets: HPV and Lynch syndrome

Tweets. Also, it uses Calinski-Harabasz index and Silhouette Coefficient to evaluate the accuracy and performance of implemented algorithms.

Liqiao Zhang et al. [9], propose a methodology of analyzing social media by using consumers' opinions. It uses different social media such as (Facebook, Twitter, Sina Weibo, etc.). Also, it includes three different collective classification algorithms (Local classifier-based method, Logistic regression classifier, Naive Bayes classifier) in the experiment and in the last part of their research shows a visualization method of results, they have reached. According to their conclusions, in the experimental part, the Gibbs sampling method with logistic regression classifier as local classifier performs the best among all the CC (collective classifier) algorithms.

Kai Wang et al. [10], proposes an e-commerce product personalized recommendation system based on learning clustering representation. Also, it uses a methodology of users' for a period time such as income, and occupations, interest. To achieve results for their dataset's [six of them with different of content (shopping, entertainment, sport, film, music and business)], it's used several unsupervised algorithms including Gaussian Mixture Model [11], K-means clustering [12], Density-Based Spatial Clustering of Applications with Noise (DBSCAN) [13], K nearest neighbors (KNN) [14], hierarchical clustering (HC) [15], multi-assignment clustering (MAC). But as a part of their research it noted that the KNN method has its limitations in selecting an adjacent object set. So, they used the neighbor factor and time function and leveraged the dynamic selection model to select the adjacent object set. Also, they combine RNN as well as an attention mechanism to design the e-commerce product results and the performance of proposed algorithms, where it shows better results in six types of dataset.

Kristina P. Sinaga and Miin-Shen Yang [16], propose a new schema with a learning framework for the k-means clustering algorithm in that way where it automatically finds an optimal number of clusters without giving any initialization and parameter selection. Some of the points that have been experimented are feature characteristics, number c of clusters, number n of instances and number f of features in 8 different datasets.

Eric K. Tokuda et al. [17] focuses in applying of agglomerative clustering using unimodal and bimodal datasets where it presents the difference of dendrogram visualization and identifying the clusters in dendrogram, The implementation idea of the proposed approach presents the cluster size s and a number of clusters *k*, the dendrogram is first obtained and then analyzed in a bottom-up approach. Clusters are merged until *k* clusters having at least *s* elements are identified for the first time. Since the last cluster merge might generate a cluster having size much larger than *s*, it is checked if the last merge should be undone.

So, we can clearly see that the chosen algorithms in this paper treat mainly language processing cases, so in our case Albanian language is very specific. Also, these algorithms are shown very successfully in several cases and we are convinced that the results obtained represent the concrete situation in this regard.

III. Research Methodology

In this section, we introduce the state-of-the-art of unsupervised clustering algorithms and sentiment analysis taken from social networks, written on Albanian language. The main focus of the algorithms used is K-Means, Spectral and Agglomerative clustering algorithms.

In our paper we will show three algorithms which we have implemented by using sentiment on social networks written on Albanian language. Problems and challenges of text preparation as in any language, also in Albanian language it has its specifics taking into account the fact of writing not only in one standard or dialect. This further complicates the preparation process or preprocessing stages as it is a very important process in this part.

A. Pre-processing of Dataset

The data that we will use in the acquired dataset are taken from social networks, where to do this we used web scraper, which are taken only the comments/ content of various posts. As a case study we take comments made on the official fan page of VALA Telecommunication[1].

Dataset contains a considerable number of comments which include the various services that the company offers including the latest offers, prices, rewards and services that they offer in the framework of their operation. The dataset is UTF-8-"latin1" encoded, since the Albanian alphabet contains some non-ASCII symbols, like ë, ç, Ç, etc. The next step is to normalize the comments, i.e. to change the comments from upper case to lower case. This step can be skipped to evaluate the influence of the normalization. To split the comments into its words and punctuation marks two different tokenizers are used: The Word2Vect and TF-IDF, which treats a simple emoticon as a single word. The next step in the process is to remove Stopwords. We adopted a list of Albanian Stopwords Ardit Dina [18], where we add more keywords to do more valuable for the implementation on Albanian, also, we comparison with others language such as in Andrej Gajduk and Ljupco Kocarev [19], Henríquez C, Guzmán J [20]. We used Stopwords because we think that it can potentially help in improving performance, and the classification accuracy improved. Now the tokens are converted into *n*-grams. To get the best results, we created a list of words which we have used as stemming of repeated words such as "Interneti", "Internetin", "Internetit", and we have extracted just in one word "Internet", this it helped increasing accuracy of algorithms and optimizing it by easy identifying assigned terms.

B. Feature Extraction

In daily life, implementing machine learning techniques on a large dataset is normal and very important to present the accuracy and originality of results. Every day and more of using social networks and associated types of communication media it produces new amounts of data. This it expresses the

[1] Public company in Republic of Kosovo (https://www.facebook.com/valamobile)

need of managing and implementing new feature extraction by adopting adequate language, whether local language or more spoken language. In fact, techniques of using feature extraction represent a part of the dimensionality reduction process, in which an initial set of the raw data is divided and reduced to more manageable groups. So, this helps the process of managing and seeing if the data are correctly divided according to language perspectives, which it makes it easier. The most important valuable element of using feature extraction on large datasets is that they have a large number of variables. And, the number of variables requires a lot of computing resources to process them. So, feature extraction also helps to get the best feature from those big datasets by selecting and combining variables into features, thus, effectively reducing the amount of data. In our case, after we implement two feature extractions where we have achieved very good results by using of TF-IDF and Word2Vect, where, this it proves that these techniques are suitable and produce original data from core dataset.

To implement TF-IDF we have used two forms of representation data, this we have seen as a process of preprocessing phase:

- Dense vectorization, and;
- Spare vectorization.

As a process, first we present the Dense Vect then the Spare Vect. The explanation of Spare Vect. is that it creates (N x N) matrix, which represents $N_{\text{(horizontal line)}}$ (terms number achieved) **x** $N_{\text{(vertical line)}}$ (number of comments/ rows), then it can be extracted in Dense Vect.

Spare Vectorization form it represents results in this way:

00 0800 080010000 10 10 dite ... zoti çdo çmim është është kosovës…
0 0.0 0.0 0.0 0.0 0.0 ... 0.0 0.0 0.0 0.0 0.0
1 0.0 0.0 0.0 0.0 0.0 ... 0.0 0.0 0.0 0.0 0.0

The list is bigger but in this case we didn't present.

Dense Vectorization form it represents results in this way:

(0, 960)	*0.4576438590753533*
(0, 490)	*0.4758177241051434*
(1, 725)	*0.7071067811865475*
(1, 527)	*0.7071067811865475*
(2, 1096)	*0.32606112714163765*
(2, 877)	*0.30343163250680155*

First column (0, 1, 2 …) shows row/ comments number, second column shows the position of the terms inside of the dataset and the last column shows weight of terms which is identified according to row and column sorting.

Regarding the implementation technique of word2vect we have used two sub-techniques such as:

- Continuous Bag of Words (CBoW), and;
- Skip-grams.

CBoW and Skip-grams have extracted similarities between terms which are used in all datasets.

C. Similarities between Terms in Dataset

CBoW:

[('punso', 0.2354489415884018), ('bane', 0.2187425047159195), ('teknikes', 0.20852388441562653), ('korruptuar', 0.20763424038887024), ('perndryshe', 0.19758988916873932), ('met', 0.19453111290931702), ('besimin', 0.19172176718711853), ('virusi', 0.18643076717853546), ('çdo', 0.18365386128425598), ('master', 0.16957449913024902)]

Skip-Gram:

[('ni', 0.38147056102752686), ('tv', 0.3492451012134552), ('keni', 0.3451632261276245), ('për', 0.34493157267570496), ('sms', 0.34084585309028625), ('vales', 0.3397885262966156), ('150', 0.3364603519439697), ('kerka', 0.3312993347644806), ('euro', 0.3179359436035156), ('ofert', 0.3156954348087311)]

While, in this part we have presented the similarities between two same terms and we present the accuracy of these sub-techniques of Word2Vect.

Table I shows the comparison of these two sub-techniques where it has generated better results for Skip-Grams than CBoW, because of accuracy that Skip-Grams has managed to extract is 0.26 while CBoW 0.05.

TABLE I. SUB-TECHNIQUES OF WORD2VECT.

Sub-Techniques of Word2Vect	
CBoW	**Skip-Grams**
0.058835257	0.2648386

IV. EXPERIMENTAL RESULTS AND ANALYSIS

As we have stated, the focus of this study is to generate and compare the performance of applications using unsupervised clustering algorithms for the sentiment taken from social networks written on Albanian language, where we have specified three of them.

The experiment was developed using the following hardware specifications: Processor: Intel(R) Core(TM) i5, 2.50GHz, RAM 8 GB, System Type: 64-bit Operating System. To see gained results from the extraction data and preprocessing phase, we have used four different criteria of filtering and producing. This, we did to have better results and to see if the data will be presented properly and correctly. This helped the visualization for each implemented algorithm.

The criteria of filtering and production data are:

- With Stopwords & N-Grams;
- With Stopwords & without using N-Grams;
- Without using Stopwords & with N-Grams;
- Without using Stopwords & N-Grams;

In every case, we have achieved a different number of terms, this because when we used N-Grams it divides in more terms such as, "Mbushje", "Mbushja", "Mbushjen" and it make implementation much more complex as a whole.

Achieved results will be presented according to algorithms, which are implemented the techniques explained.

A. K-Means

K-means clustering is a classical clustering method based on data partitioning according to *Hao Yu et al.* [21]. The main idea is to gather the original data into *k* clusters, so that samples with similar attributes are in the same cluster. The main processing procedure is as follows: Firstly, *k* samples are randomly selected from the original data, each sample is taken as the center of *k* clusters, and then the distance between the remaining samples and the *k* center samples is separately calculated, each sample is divided into its nearest center. In total, we achieved three clusters such as Cluster 0, Cluster 1 and Cluster 2. Most of the sentiment is clustered in cluster 0 because it has similar terms between them, than in cluster 2 and the last one is shown in cluster 1. These results are shown in Fig. 1; we have presented a visualization and seen how they stand on this form.

In this way, we have analyzed and shown the mini-framework of K-Means, how it works by using sentiment on Albanian language. The results achieved are satisfactory because of putting centroids in three clusters and every comment which is related to its centroids. The visualization is shown in Fig. 2 where we can clearly see it in three different colors. With yellow representing cluster 1, green is for cluster 2 and the most classified comments from K-Means are clustered in cluster 0 which are in purple.

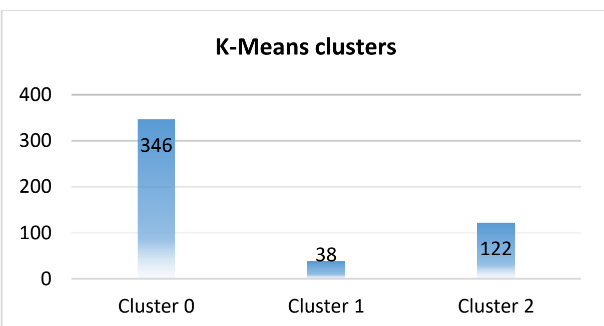

Fig. 1. K-Means Clusters.

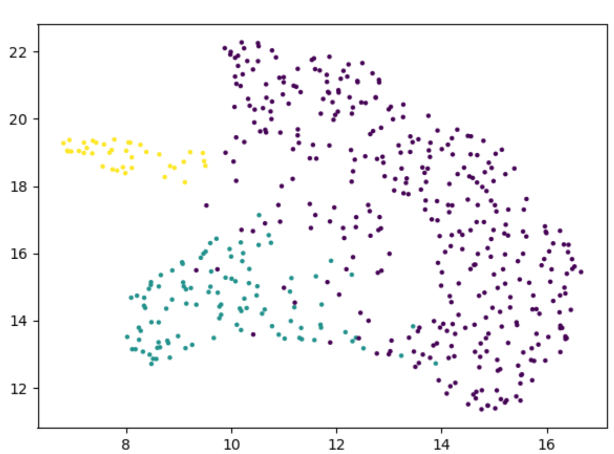

Fig. 2. K-Means Cluster Results.

Our proposed application form of the algorithm is optimized and it is faster than several proposed algorithms in other different researches and examples such as [16], [22] and [23] which are implemented in different cases and datasets. So, the execution time of our proposed form of implementation on Albanian language is 1.662015799999999 seconds. To see and prove, if our visualization is correct and our results correspond with the real statement of implementation we used the silhouette coefficient, to see what kind of results will produce. As we know, silhouette coefficients study and present the separation of distance between the resulting clusters. Also, it computes for each point a width depending on its membership in any cluster. This silhouette width is then an average over all observations according to [8].

This is based on:

$$SC_k = \frac{1}{n} \times \sum_{i}^{n} \frac{b_{i-}a_i}{\max(a_{i,}b_i)}$$

Where, n represents the total number of elements in a cluster, a_i is the average distance between an element i of the cluster and all other elements within the same cluster, b_i represents the average distance between the element i of the cluster and all other elements in the nearest cluster.

Also, we have used silhouette to predict what is the best form of visualization with our dataset. And the results are shown in Fig. 3.

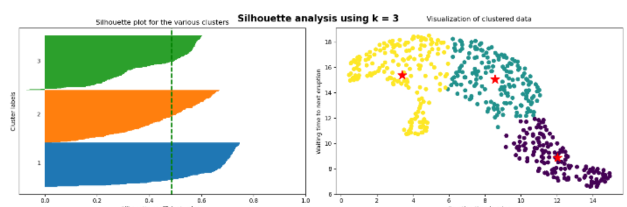

Fig. 3. Silhouette Prediction using Dataset.

While, accuracy is identified with two, three and four clusters presented in percentage in Table II:

TABLE II. SILHOUETTE SCORE WITH DIFFERENT NUMBER OF CLUSTERS

Silhouette clusters accuracy	
Number of clusters: 2	0.7108542990876117
Number of clusters: 3	0.6360185043007658
Number of clusters: 4	0.5455599807949814

B. Spectral Clustering

Spectral Clustering is one of the best known unsupervised algorithms, where, it has performed better than many traditional clustering algorithms in many cases, where we mentioned in related work.

Spectral uses the connectivity approach of clustering, wherein, the parts of nodes (i.e. terms it uses) immediately are next to each other, identified in graphs. The term or connectivity form is then mapped to a low-dimensional space that can be easily segregated to form clusters. Spectral algorithms use data from the eigenvalues of the matrices it created by it i.e. Affinity Matrix, Degree Matrix and Laplacian Matrix derived from the graph or the data we use for our experiment. In our case, we have used the best known techniques for spectral algorithms and the number of clusters' in total are three of them. The most common comments classification is cluster 0 where it has achieved 330 from the total of the dataset, then cluster 1 classified 131 comments and the last one cluster 2 classified 45 comments. These results are shown in Fig. 4, graph model of classification comments for each cluster's.

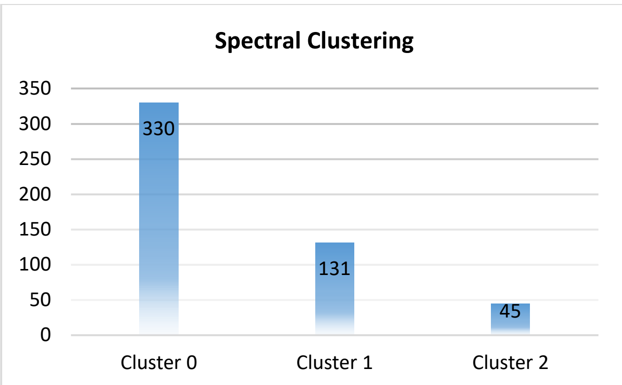

Fig. 4. Spectral Clusters.

Also, spectral clustering visualizes three different colors, which represent each cluster in Fig. 5. For cluster 0 it is purple, green cluster 1 and cluster 2 it's in yellow color. The accuracy of related comment classification with colors are separated very well because the possibility of error is very small, whereas, it seems only three comments which are not classified as it should be but they are missing. Also, we think that as many comments there are in the dataset, the accuracy will be higher. This is because the algorithm can train itself and identify key terms how to separate for each cluster.

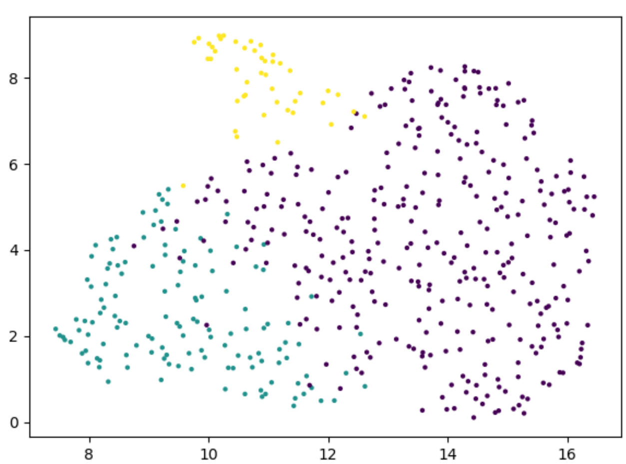

Fig. 5. Spectral Clusters.

C. Agglomerative Clustering

The agglomerative algorithm is part of family algorithms which execute hierarchical clustering. The form of implementation is by grouping objects in clusters based on their terms which are generated by passing preprocessing phases. The main element which increases the accuracy of AC is feature extraction, specifically spare and dense vectorization. The focus of the algorithm is by treating each object as a singleton cluster. In our case, each comment is identified according to the content which is placed in a group of clusters and as seen in Fig. 6, they take on a certain color as a separate cluster. Then, the algorithm continues to compare with other groups of clusters, which, according to the similarities they have managed to make another special group which takes on another special color until the classification of a group in the form of hierarchical clustering as it is presented in Fig. 6. This form of implementation helps algorithms to increase accuracy and present visualization in the best form. So, the results are generated and the algorithm was successful by dividing comments in precisely form for the cluster it should be. The process of clustering is known as hierarchical/ dendrogram model of clustering.

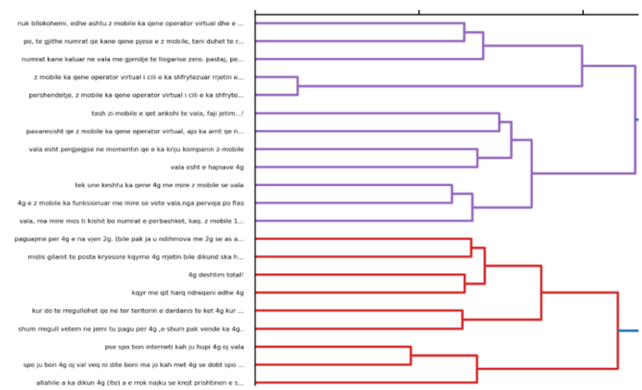

Fig. 6. Agglomerative Clusters.

The list of results it's bigger than it's presented but this is just to understand the idea and results achieved of implementation in our experiment.

V. Conclusion

In this paper, we have applied and tested which of the three selected algorithms is most suitable for the Albanian language. Results obtained are extracted by using the same dataset for three algorithms but the results are different between algorithms. The optimization of each of the algorithms has shown growth and efficiency, as we have presented in this paper the accuracy of the execution of K-Means algorithm dividing into two clusters is 0.71%, three clusters is 0.63% and four clusters is 0.54%. While other algorithms such as Spectral and Agglomerative have shown better results on identification and comparison through terms which create main centroids than groups of their clusters. The best example in our experiments is Agglomerative because the idea of implementation is hierarchical grouping data. So, this is the reason why we have taken only three clusters to see achieved results where this helps to take the average of identifying comments in better form. Finally, we consider that this work is just the first step to improve the accuracy of *k*-means, spectral and agglomerative clustering of dataset/ corpus written in Albanian language. The machine learning models, such as K-Means, Spectral and Agglomerative were used in several different languages but it's the first time on

Albanian according to the best of our knowledge. But, that the techniques and results obtained in this paper help to identify and facilitate the form of use in other content. So, we mention sentiment analysis of consumer in different businesses such as restaurants, hotel, public services, sports and patient impression about the services they receive which they express in several social networks which are written especially on Albanian language. Also, the limitations of this paper are mainly limited academic literature and professional real implementation of surrounding text analytics of social network data. Also the limitations of the work was the lack of research and the form of implementation of the algorithms mentioned for the Albanian language, has shortcomings and needs to be worked on even more in this regard. Future work in this field can also be focused on real-time analytics of social network data streams and improving accuracy and trying to give solutions on distinguishing the dialect of the Albanian language. Also, theoretical analysis and experiments on a benchmark dataset have presented the superiority of our proposed method.

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Mitigating Traffic Congestion at Road Junction using Fuzzy Logic

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***Abstract*—The timing of traffic lights at intersections is determined by the Local Authority. It is based on the peak hour statistics and the timing is maintained even during an off-peak hour. This one standard green time will be used every time in a day regardless of the number of vehicles and the road width. This approach will have a long green traffic light even though the number of vehicles is only a few and hence, will cause a long waiting time at the intersections. Therefore, the aim of this study is to vary the timing of traffic lights at junctions according to the number of vehicles. This paper will also consider road width variable which have not been considered so far. Fuzzy logic rules will be used to classify the number of vehicles and road width and time taken for vehicles to move at the intersections which was proposed in a previous work. The new timing will commensurate with the number of vehicles and road width. Field test data were gathered from Sala Benda and Semplak intersections which are amongst the busiest intersections in Bogor, Indonesia. Comparisons were made and show that the green light timing obtained is appropriate to the two factors considered. Also the waiting time for vehicles in each traffic cycle was also reduced. This study have formulated an optimal green lights timing in each intersection and will be used by local authorities to determine the timing of green traffic lights at the intersection and hence, can implement traffic control and an appropriate waiting time.**

Keywords—Traffic fuzzy classification; congestion; traffic lights control

I. Introduction

Monitoring and controlling city traffic are a big problem in many countries. Indonesia is one of the highest traffic conglomerates in the world with the capital Jakarta as the largest and densest urbanized area in Indonesia [1]. One of the causes of traffic congestion is the large population (4th place in the world) and an unbalanced distribution of the Indonesian population [2]. With the huge population and consequently increasing vehicle ownership on the highways and thus the need for traffic control on the highways, the Department of Traffic and Road Transport (DLLAJR), the Ministry of Transport as the main authority in Indonesia need to find new ways or steps to resolve this problem. The steps taken by the Ministry of Transport have included the development of new roads and bridges in the city center, the development of several highways in the city as internal, middle and outer lanes as well as public transport acquisitions such as Light Rail Transit (LRT), Public Transit (MRT) and various new mode buses namely Transjakarta, Transbogor. Given the rapid growth of population and large urban development as well as human activities and life spans, it is undeniable that almost every major city in Indonesia faces serious transport problems, including traffic congestion and delays, especially at intersections. Traffic congestion can cause many problems, and has the biggest impact that road users will face. Vehicles on the road will experience a deep decline in travel speed, requires longer travel time. The effect is that the cost of travel such as time, fuel consumption, wear and tear, carbon emissions and so on, must be borne by road users.

The road system of any country is basically a network of roads that cover all places and regions. The highways will be built to accommodate high traffic between major cities. From here, the highway will have several entrances and exits to connect business centers, residences, government administration offices and even schools or colleges. Therefore, the road system will have many intersections. The traffic light system is a means of traffic management at the intersection to provide a system of circular motion between the intersections of the intersection. With this movement system, it will reduce accidents and be organized as well as give you the right to cross at all intersections.

Local authorities in Indonesia refer closely the Manual Kapasiti Jalan Indonesia (MKJI) [3] or Indonesia Road Capacity Manual (IRCM) to determine the traffic lights timing at each junction which is a one standard time used throughout the day. The number of vehicles on the road varies to the time of day where a high number of vehicles can be seen in the morning for office workers commuting to work, the business traffic at mid-morning, lunch traffic and going home traffic. In between these times and also during the weekends, the traffic has a different profile throughout the day. This will result in long waiting time for junctions with fewer vehicles. Hence, it is hoped that with varying the green time according to the number of vehicles, the waiting time will be greatly reduced.

II. Literature Study

This literary study will provide an overview of the setting of green lights followed by the discussion of traffic light modelling focusing on the classification of traffic light timing at intersections. And lastly, a review traffic monitoring methods at junctions.

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A. Overview of Green Lights Settings

In Indonesia, the timing of the traffic light at the intersection is determined by reference to the Manual Kapasiti Jalan Indonesia (MKJI) [3] or Indonesia Road Capacity Manual (IRCM) solely using one standard time. The manual explained that the average number of vehicles is the basis for determining the daytime green light setting taken during peak hour traffic. This means that the green light is fixed and does not change although the number of vehicles at a given time is fewer or greater than the peak time scenario. This will affect other junctions in the same intersection as more time are allocated to the branch [4][5]. Also, it will cause a delay due to long waiting time in cases that there are few vehicles in the branch. Adjusting the green time according to the number of vehicles should be analyzed so that each junction of the intersection will be given an appropriate time to allow all vehicles to pass the junction. The author in [6] mentioned that the control at traffic lights is important but the author proposed using RFID. Data from traffic monitoring is in the form of vehicle densities, and current behavior of the junction must be captured in real-time.

B. Traffic Light Modelling

In an effort to mimic the behavior of traffic lights, mathematical models have been created and can be used to make theoretical models. The mathematical description of the general features of signal processing modeling has been studied for more than four decades [7]. Based on the traffic light model with image processing, it also uses an artificial intelligence model to determine signal lights. Fuzzy logic model [8] is a method of fuzzy inference system, in which the estimation of the behavior of the signal lights, and the accuracy of the model depends on the number of vehicles. The signal light controller is designed for crossing traffic based on a normal system using a single two-way intersection.

The system in Fig. 1 is an automatic signal transmission using an IR sensor and a Microcontroller. The top-down design approach is adopted [8]. This approach involves breaking down the system into smaller units to allow designers to gain more insight into the system. The system is broken down into several units which are Power Supply Unit, Control Unit and Sensor Unit. From the tests conducted on the circuit, it is observed that LEDs of the same color have the same time, and that each of the four poles of the traffic light controls, alternating and repeating until the circuit is disconnected from power.

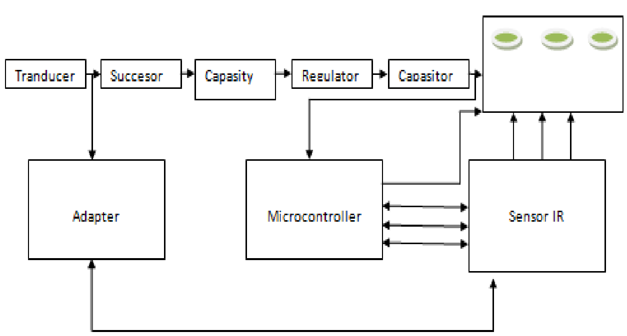

Fig. 1. Block Diagram of the Intersection Model System [23].

Sensors help in keeping the count of vehicles entering the road and the microcontroller then allocates an appropriate time delay as to give the right priority to each road. The microcontroller used is an optocoupler, used to provide coupling while ensuring electrical isolation between input and output. Another purpose of an optocoupler is to prevent rapid voltage or high voltage changes on one side of the circuit from transmission deviations or damage components on the other side of the circuit. This new design will reduce time delays, increase efficiency and reduce accidents by including modifications [8].

Other models for determining signal traffic using Fuzzy smart circuits are, the results of frequency simulation (number of cars completing cycles) per minute for predetermined (fixed) traffic control and fuzzy logic traffic control systems [9][10][11]. According to analysis, the fuzzy logic traffic control system consistently performs better because it has a higher frequency (number of cars completing cycles) at a certain point in time. However, it should be noted that there are variations in performance at certain time points where the number of cars completing cycles is relatively higher for fuzzy logic traffic control systems than for pre-time (fixed) traffic control systems [12]. The researchers interpreted this finding as a further indicator of performance improvement in fuzzy logic traffic control systems based on estimates at certain points during high traffic density, so that the number of cars completing the cycle was slightly higher than the density in low traffic [13][14].

TOPSIS Fuzzy Algorithm is a new method using problem solving to understand the human behavior on the decision making [1]. The TOPSIS Fuzzy Algorithm concept which must have the shortest geometry distance from the positive ideal solution and the longest geometry distance for the negative ideal solution. This fuzzy method determines the traffic lights by determining the length of the vehicle closest to the traffic light on. This study produces an optimal green light time but however only consider the number of vehicles in the branch only.

C. Traffic Monitoring

To determine the average traffic density, it is necessary to monitor the number of vehicles passing the highway [15] Monitoring is usually carried out by observers. The observers sometime will generate errors in the calculation process due to vehicle congestion, environmental influences or internal investigators themselves [17][18]. In addition, human calculations require separate costs which indicate the implementation becomes less efficient [8]. Therefore, this study will also design and calculate the number of vehicles on the branch, using cameras and C ++ programming with the OpenCV library (18). OpenCV is used as its own subprogram or library which can be combined to be multiple functions in the programming which relates to digital image.

The author in [19] proposes a case in which the traffic junction topology monitoring will control traffic light systems. The system uses a camera which is connected to the computer and is place at the center of the junction and it has multiple sensors based on RFID. ZigBee traffic monitoring will be depending on the parameter used in the traffic monitoring.

Measurements are made to determine the number of vehicles, movement and classification of the vehicle at a certain location.

Another work by [20] is developed to combine the dynamic smart algorithm to monitor and predict the parameter strategy for traffic light. This system used wireless technology and low power energy. This system is going to be one of the traffic light systems that are very effective in Taiwan [8].

In discussing the traffic light system, there is a huge gap where road width was not considered when determining the green time. Therefore, a clearer and accurate determination of green timing at traffic lights that considers the number of vehicles and road width would appropriately reduce the traffic congestion due to ineffective green light timing is the main focus of this paper. This work will also consider the time taken to cross the junction based on values proposed by [1][11] Fuzzy classification will be the focal of this work. By monitoring, examining and determining the number of vehicles that will pass the junctions and the road width, it can determine the green light time with respect to the NWHS proposed by [1][21].

III. Methodology

The overall methodology is shown in Fig. 2 which illustrates the two inputs required that is the road width and the number of vehicles in the branch. The output is the appropriate green time at the intersection. The method will use image processing at the intersection to determine the number of vehicles and use Google maps to determine the width of the road. Both inputs will be used for the classification in Fuzzy logic which will determine various levels of membership, then will be used to determine the level of green time membership. The original equation in IRCM will be modified to include the road width criteria and the proposed NWHS from [1].

A. Fuzzy Rule Recommendations and Green Classifications

Fuzzy logic is one way to map the input space to the output space [4] [10]. The fuzzy logic has been selected to map data input points to membership values or referring to membership levels with fuzzy sets. The first step in computing is to create a set of fuzzy variables [22]. There are two input variables that have been indicated by their degree of membership, namely the number of vehicles (few, moderate and many), width of the road (wide, medium and narrow) [16][23]. The green light output, on the other hand, is short, moderate and long membership. The fuzzy assembly for each variant is shown in Table I.

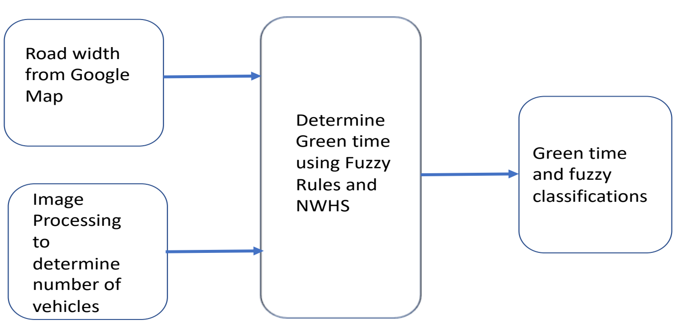

Fig. 2. Research Method of Traffic Controller (TC).

TABLE I. FUZZY LOGIC INPUT AND OUTPUT CRITERIA

Functions	Criterion	Fuzzy classification
Input	Number of vehicles	Few
		Moderate
		Many
	Road width	Wide
		Medium
		Narrow
Output	Green Time	Short
		Moderate
		Long

The inputs were further detailed as given in Table II. Determination of the number of vehicles from the camera, mapped to degree of membership is illustrated as a straight line using the data in the table. The number of vehicles were classified into three categories, namely, many, moderate and few vehicles; for example, many vehicles are in the range of 20 to 60 vehicles.

Road width (LJ) denotes the width of the road; however, further modification was used which is the LJ coefficient factor. This factor is based on the number of lanes that the width of the road can accommodate. Having several lanes in the branch will increase the number of vehicles to cross the junction at each click timing. For example, the number of vehicles to pass the junction is doubled if the LJ coefficient is 2. And the same calculation for other road width is given in Table II.

In this study, the value of NWHS as proposed by [3] where the average value of all possible types of vehicles on the road is used. The image processing capability will determine the number of vehicles only but not the type of vehicles that crosses the junction. From [1], car took 1.86 seconds to cross, the bus took 2.58 seconds while the truck took 2.77 seconds. Because vehicles on the road in Bogor are a combination of these three types of vehicles, they will certainly affect the short-term movement of vehicles. This is the reason why the NWHS value used in this work has been modified as the average time of all number of cars, buses and trucks take to cross the road and has a value of 2.73 seconds. This value was not considered in previous work.

TABLE II. FUZZY LOGIC INPUT CRITERIA

No	***Criterion***	***Number of vehicles***
1	Few vehicles	2 – 8 units
2	Moderate vehicles	7 – 25 units
3	Many vehicles	20 – 60 units
No	***Criterion***	***LJ coefficient factor***
1.	Narrow Road (1m - 3 m)	1
2.	Medium Road (2 m – 6 m)	2
3.	Wide (5 m - 10 m)	3
No	***Vehicle Movement Time***	***NWHS* [Galang et al 2018]**
1.	Car	1.86 s
2.	Bus	2.58 s
3.	Truck	3.77 s

The following Fuzzy rules were used to classify the green time output for all JK and JK input conditions that were previously categorized as above. The Fuzzy Rule Recommendations for the green light consists of nine rules and are as follows:

a) If the number of vehicles in the branch is many and the road width is wide then the green time is short.

b) If the number of vehicles in the branch is many and the road width is medium then the green time is moderate.

c) If the number of vehicles in the branch is many and the road width is narrow then the green time is long.

d) If the number of vehicles in the branch is moderate and the road width is wide then the green time is short.

e) If the number of vehicles in the branch is moderate and the road width is medium then the green time is moderate.

f) If the number of vehicles on the branch is moderate and the road width is narrow then the green time is long.

g) If the number of vehicles in the branch is few and the road width is wide then the green time is short.

h) If the number of vehicles in the branch is few and the road width is medium while the green time is moderate.

i) If the number of vehicles on the branch is few and the road width is narrow then the green time is long.

The graphical representation of the nine rules is illustrated in Fig. 3.

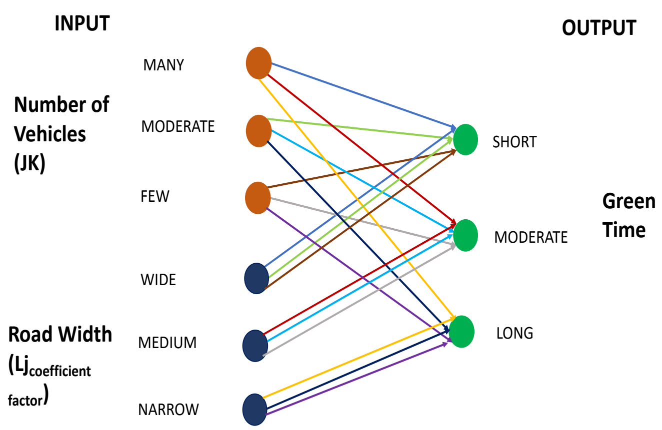

Fig. 3. Schematic Fuzzy Rules to Determine the Output Green Time.

B. Determination of Green Lights Time

From IRCM, the original equation did not consider the road width and since the number of lanes that can be determined based on the road width, therefore, the LJ coefficient factor is used and not the exact road width. Therefore, Equation (1) shows the green time formula used in this research and is expressed as in

$$€ = \frac{JK}{LJ_{coefficient\ factor}} * NWHS \quad (1)$$

where

€ = Green Time in seconds

JK = Total number of Vehicles

$LJ_{coefficient\ factor}$ = Road Width coefficient factor

NWHS = 2.73 s

Equation (1) is the equation used in Traffic Controller (TC) algorithm which uses two inputs that is the number of vehicles (JK) and LJ $_{coefficient\ factor}$. The intersections to be studied are the Sala Benda and Semplak intersections. From Table II and the nine fuzzy rules, the green time for each class of vehicles (many, moderate or few) and each class of road width (wide, medium or narrow) will be calculated using Equation (1). Only the highest number of vehicles in each category are used (many=60, moderate=25, few=8) while the LJ coefficient factor will be 1, 2 or 3 depends on the road width at Sala Benda and Semplak intersections. These values were calculated for each input category of vehicles and road width. The output will be the three categories and the range of green time are short, moderate and long as given in the following and also follow the nine fuzzy rules and shown schematically in Fig. 3.

Range of Short Green time : {7.3, 22, 54} secs

Range of Moderate Green time : {11, 34, 82}secs

Range of Long Green time : {22, 68, 164}secs

The classification of green time is shown in Fig. 4, where it depicts the LJ coefficient of 1 and 3 only.

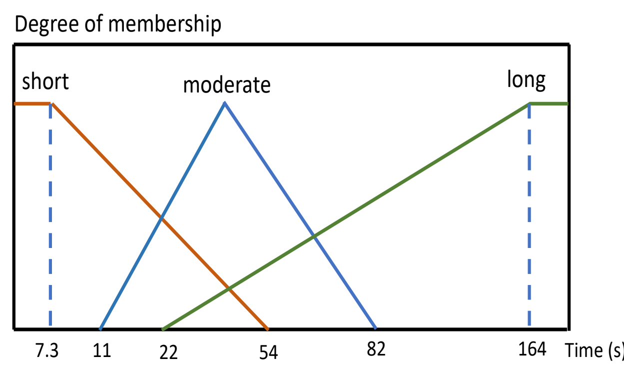

Fig. 4. Classification of Green Time.

IV. RESULTS

Data collected from Sala Benda intersection are tabulated in Table III while Table IV has data collected for Semplak intersection. The number of vehicles and the timing of the green lights are recorded and road width is obtained from Google Map. These are the data for MKJI system. The results of the calculation of the number of vehicles at the crossing of the Sala Benda and the video capture were captured between 10:00 and 10:30 and the vehicle calculation is about 80% accurate.

A. Inspection at the Sala Benda Intersection

The Sala Benda has three branches and road width obtained from Google Maps is 6.96 meters for branch 1, 6.73 meters for branch 2 while branch 3 is 7.03 meters. Based on Table I, all 3 branches have LJ coefficient factor of 3. Data was collected at 9 am to 10 am and also at 12 noon to 1 pm and as shown in Table III.

TABLE III. MKJI DATA AT SALA BENDA INTERSECTION

Nos	Details	Branch 1	Branch2	Branch 3
	Road Width (m) (LJ coeff factor)	6.96 (3)	6.73 (3)	7.03 (3)
1	No. of vehicles	43	47	37
	Green Time	55	62	37
2	No. of vehicles	41	46	25
	Green Time	55	62	37
3	No. of vehicles	44	45	23
	Green Time	55	62	37
4	No. of vehicles	5	12	11
	Green Time	55	62	37

B. Inspection at the Semplak Intersection

Semplak has four different branches and the width of the branch 1is 6.96 meters, branch 2 is 7.19 meters, branch 3 is 6.86 meters, and branch 4 is 7.11m obtained from Google Maps also. With these widths, the LJ coefficient factor is 3 for all branches. Refer Table IV.

TABLE IV. MKJI DATA AT SEMPLAK INTERSECTION

Nos.	Details	Branch 1	Branch 2	Branch 3	Branch 4
	Road width (m) (LJ coeff factor)	6.96 (3)	7.19 (3)	6.86 (3)	7.11 (3)
1	No of vehicles	23	37	34	54
	Green Time	33	67	37	66
2	No of vehicles	29	25	25	51
	Green Time	33	67	37	66
3	No of vehicles	22	41	37	50
	Green Time	33	67	37	66
4	No of vehicles	23	27	26	52
	Green Time	33	67	37	66

Notice that the green time for MKJI is also found at the intersection where the green time is constant in each branch despite the changing number of vehicles. This is the basic approach that is followed in MKJI.

C. Comparison between MKJI and TC

Using Equation (1), the green time of each simulation and for each branch were calculated as shown in Table V and Table VI. The difference in green time using the MKJI and TCs are also given. The waiting time for both MKJI and TC were also shown which the total waiting experience by all branches for every cycle.

As illustrated in Table V, at Sala Benda, the green time depends on the number of vehicles in the branch and shows a difference in timing ranging from -9 % to -91%. As discussed in the literature, MKJI gets the green time during peak hour in a day. This means that the green time will not change if the number of vehicles decreases or increases, in other words MKJI is fixed throughout the day. For TC, the green time will change according to the number of vehicles queueing in each branch. Also shown in the same table is the waiting time for vehicles in the next branch waiting for the traffic light at their branch to be green.

TABLE V. COMPARISON OF MKJI GREEN TIME WITH TC AT SALA BENDA

Nos.	Branch	Green time (s)		% of Diff. in green time	Waiting time(s)	
		MKJI	TC		MKJI	TC
1	1	55	39.13	-29	0	0
	2	62	42.77	-31	55	39.13
	3	37	33.67	-9	117	81.9
2	1	55	37.31	-32	0	0
	2	62	41.86	-32	55	37.31
	3	37	22.75	-38	117	79.17
3	1	55	40.04	-27	0	0
	2	62	40.95	-33	55	40.04
	3	37	20.93	-43	117	80.99
4	1	55	4.55	-91	0	0
	2	62	10.92	-82	55	4.55
	3	37	10.01	-72	117	15.47

TABLE VI. COMPARISON OF MKJI GREEN TIME WITH TC AT SEMPLAK

Nos.	Branch	Green time (s)		% of Diff. in green time	Waiting time(s)	
		MKJI	TC		MKJI	TC
1	1	33	20.93	-36.57	0	0
	2	67	33.67	-49.75	33	20.93
	3	37	30.94	-16.37	100	54.6
	4	66	50.94	-22.82	137	85.54
2	1	33	26.93	-18.39	0	0
	2	67	22.75	-66.04	37	26.93
	3	37	22.75	-38.51	100	49.68
	4	66	50.21	-23.92	137	72.43
3	1	33	18.97	-42.52	0	0
	2	67	39.92	-73.19	37	18.97
	3	37	37.76	2.05	100	58.89
	4	66	45.50	-59.85	137	96.65
4	1	33	20.93	-36.57	0	0
	2	67	24.57	-63.33	37	20.93
	3	37	23.66	-36.05	100	45.5
	4	66	47.32	-28.30	137	69.16

As illustrated, in Table VI, at Semplak intersections which has four branches, the green time depends on the number of vehicles in the branch and shows a percentage difference in timing ranging from +2 % to -73.16%. MKJI gets the green time during peak hour in a day and this means that the green time will not change if the number of vehicles decreases or increases. In other words, MKJI is fixed throughout the day.

Comparing the waiting time at Sala Benda, the waiting time correspond to the number of vehicles in each branch. In other words, smaller number of vehicles will have a small green time and hence less waiting time. For the first simulation, branch 3 has to wait for a total of 81.9 seconds to start crossing the intersection for TC while for MKJI, vehicle in branch 3 has to wait for a total of 117 seconds. Other simulations also show the same profile and have less waiting time for TC compared to MKJI.

V. Conclusion

This project shows that incorporating the number of vehicles and road width in TC implementation, using fuzzy logic, have shown that optimization of green time at traffic lights can reduce congestion. The difference in green time obtained from the simulation compared to the field test at the intersection of Sala Benda is very significant with a range of difference from - 9.00% to - 91.0% and at the intersection of Semplak from + 2.05% to -73.19%. This shows that with the TC method, the green time at Sala Benda and Semplak intersections can be adjusted based on the number of vehicles and the width of the road in the field.

The findings of this study can also provide three classifications of green time at intersections using TC methods as the basis for the fuzzy rules used. This Fuzzy rule was formulated using three categories of the number of vehicles namely many, medium and few vehicles with road width input categorized into 1 lane, 2 lanes and 3 lanes. From here, based on TC, green time are classified as short time ranges from {7.3, 22, 54} seconds each for a width of 1 lane, 2 lanes and three lanes respectively; moderate time ranges from {11, 34, 82} seconds while the long green time times ranges from {22, 68, 164} seconds. This is in contrast to the MKJI which gives a green time day value for the whole day, regardless of how many vehicles are lined up at the intersection.

The proposed TC compared to the work of other researchers is much better in terms of green time. Previous work uses the input of the number of vehicles only, whereas the intersection of four branches is more complex. TC uses the number of vehicles and the width of the road. Incorporating road width in traffic light system has not been done in previous work proposed to reduce congestion. This work shows a good performance in terms of optimizing the amount of green time as needed, if the traffic light setting uses TC rules then the result is green time according to the number of vehicles and short waiting time in the next branch depending on the arrival of the vehicles in each phase.

Based on the classification of green time given in Section III(B), at Sala Benda and Semplak intersections, all timings can be classified to have short green time which ranges from 7.3 to 54 seconds.

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Adaptive Demand Response Management System using Polymorphic Bayesian Inference Supported Multilayer Analytics

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***Abstract*—The most significant limitation of stand-alone microgrid systems is the challenge of meeting unexpected additional demands. If demand exceeds the capacity of a stand-alone system, the system may be unable to satisfy demand. This issue is alleviated in grid-connected technology since the utility system will provide more power if it is demanded. As a result, load scheduling is an integral element of the demand response of a standalone system. There are two components to this problem. If the capacity of a battery-supported power system is restricted, for the period of time that the source is available, it will not be able to meet the entire demand. Appropriately the demand is dispersed across a period of time until the next charge becomes available. Some demands may be disregarded in order to accomplish peak load trimming or if the system is incapable of meeting demand without compromising other important technical and consumer objectives. This is a challenging assignment. This article aims to develop an Adaptive Demand Response Management System (ADRMS) capable of load scheduling and load shedding using an interwoven multidimensional Bayesian inference supported by multiple mathematical models. A two-stage hardware architecture is being developed, with the first hardware measuring demand and source capacity before sending the data to the second hardware via LPWAN for mathematical analysis. In the first phase, two approaches are used to forecast demand: Gaussian Naive Bayes Model (GNBM) and Bayesian Structural Time Series analysis. GNBM is rapid but fails to properly forecast the output when there is zero frequency error whereas BSTS can offer more precise results than GNBM but is slower. Hence two approaches are employed in tandem. The next stage is to assign demand source integration. This is accomplished using Bayesian Reinforcement Learning (BRL), which is based on a number of incentives, including anomaly, cost factors, usefulness, reliability, and size. All Bayesian models are subjected to much of the common Bayes rule, resulting in the formulation of a blended polymorphism model that reduces computing time and memory allocation, and improves processing reliability. The Isolation Forest (IF) method is used to identify and avoid vulnerable loads by determining demand anomalies. The last step employs a Dynamic Preemptive Priority Round Robin (DPPRR) algorithm for preemptive priority based load scheduling based on forecasted data to allocate the next loads to be added.**

Keywords*—Adaptive control; Bayesian; demand response; energy management system; load scheduling

I. Introduction

A. Background

Increased Solar Photovoltaic Generation System (SPVGS) installations have enabled many residential, commercial, and industrial facilities to operate as stand-alone microgrids [1][2]. In such systems, SPVGS will deliver energy to demand throughout the day, with a portion of it being stored in battery systems [3]. When solar energy is in short supply, especially at night, the stored energy from the Battery Energy Storage System (BESS) is used to satisfy demand [4]. Because of limited power capacity, demand response management is a key challenge in standalone solar-powered battery systems [5]. If demand rises in a grid-connected system, additional power can be pulled from the utility grid [6]. However, the capacity of the standalone system is constrained [7]. If the load exceeds supply limit, the system will have to drop certain loads in order to maintain the demand-supply balance [8]. The watt hour capacity of a BESS limits the amount of power it can supply [9]. Consequently, if several loads are connected and the total watt hour demand exceeds the watt hour capacity of the entire storage system, some of the loads must be bypassed. The BESS is charged from the additional supply from the SPVGS [10]. As a result, if the load is close enough to the SPVGS supply, the BESS will be drained because there will not be enough power to charge it. A portion of the load is evacuated in these circumstances to free up energy to charge the BESS [11]. It is a significant challenge to develop demand response models that satisfy all of the above characteristics while remaining efficient, cost-effective, and consumer-friendly [12]. Thereupon, numerous researches on load scheduling and intelligent demand management for stand-alone systems are now being undertaken.

B. Literature Review

Sharda et.al. investigate the overview, problems, and potential of Demand Management (DM) in standalone systems [13]. They also address real-world problems encountered while implementing DM with load scheduling for home energy management systems. Lu, Xinhui, et. al. investigated supply and demand side optimal load scheduling in a smart grid system, with an emphasis on economic, social, and environmental benefits for all market participants [14]. O'Shaughnessy et. al. looked into the end-user economics of

BESS and DM that boost the value of SPVGS by regulating and temporally altering their output [15]. The preceding papers offer an overview of the factors that go into load scheduling for stand-alone systems. The topologies of reconfigurable battery management systems are investigated by Viswanathan et. al., with an emphasis on load interface protocols and load scheduling optimization approaches [16]. Sanjari et. al. developed an optimum control approach for battery-integrated energy systems that uses analytical rather than numerical approximation methods to account for load demand unpredictability [17]. Md Masud et. al. developed a model for a hybrid gas turbine generator, SPVGS, and Battery Energy Storage System (BESS) for isolated microgrids [18]. Jonathan T. Lee et.al. experimented with non-intrusive load control in energy-constrained microgrids under unpredictable load conditions [19]. To address load management concerns, the aforementioned articles use a wide range of methods, and many of the solutions use time-based optimization methodologies. Traditional time series analysis techniques use historical data to forecast model parameters. Because the loads are only coupled for a short period of time, in most circumstances, the load gradients comprise zero values across the curve. Standard time series approaches for load forecasting are contentious due to the difficulty in distinguishing seasonality or stationarity in the zero gradient curve. This problem can be solved using a structural model, in which the parameters are expressed as the composite of individual parameter contributions, or probabilistic prediction procedures. Bruce G. Marcot et. al., provide a great deal of information on recent advances in Bayesian network modeling and integration of Bayesian rule engine for series analysis [20]. Steven L et. al. demonstrate how to integrate a structural time series model for the target series with a regression component that takes real-time search query data inputs into account [21]. The application of a spike-and-slab prior on the regression coefficients results in sparsity, which significantly reduces the size of the regression problem. As a result, in the event of uncertainty, Bayesian modeling will be an appropriate approach for load forecasting.

C. Objectives

The ideal goal of a Demand Response Management System (DRMS) is to ensure that the load receives consistent electricity. However, if the sources' capacity is limited, especially in a freestanding grid, a portion of the load is dropped or rescheduled over time to satisfy the demand via peak load cutting. An intelligent DRMS should be capable of load scheduling and load shedding in order to achieve maximum power efficiency, optimum economic gain, and user satisfaction. In order to perform load scheduling and shedding, the system should be able to distinguish between loads and determine which loads should be maintained or discarded. The DRMS should have the potential to ascertain when and for how long each load should be scheduled and shed. This is a difficult undertaking that might be accomplished utilizing a variety of mathematical methods. Because of the non-uniform zero gradients in the load curve, utilizing time spectrum analysis alone is less successful. As a consequence, a new hybrid mathematical model for analysis that combines the properties of time series analysis, spectrum analysis, and probabilistic regression is to be established.

D. Contributions

The objective of this project is to establish a multi-layer DRMS hardware that uses a two-stage hardware architecture for energy monitoring and decision making. An edge controller transforms a Wi-Fi module into an energy monitoring circuit that monitors demand and source capacity and delivers the data to a Centralized Data Processing Unit (CDPU). CDPU will save this information in a database and analyses it using a blend of mathematical models. To begin with, the Isolation Forest (IF) algorithm will be utilized to evaluate anomalies in load data. This data is used to construct a Bayesian prior. A two-stage time-series analysis is employed in the following step, using Gaussian Naive Bayes Model (GNBM) and Bayesian Structural Time Series (BSTS). One of the weaknesses of Naive-Bayes is frequency error, which causes the probability estimate to be zero if there are null-gradients in load data. BSTS can address this issue and is more accurate than GNBM, but it is also slower. Therefore, GNBM is frequently used for load forecasting, with BSTS employed in tandem if there is a zero frequency error or a significant RMSE. A Bayesian Reinforcement Learning (BRL) algorithm is utilized to identify the optimal load-source assignment combination based on the projected values. In a preemptive priority assessments approach, a Round Robin algorithm supplemented by a Dynamic Programming model is used to select the best sources from all available sources and schedule loads.

E. Organization

The paper is split into three sections. The first part is an introduction that examines the context of the problem, conducts a thorough literature review, and formulates the problem. The described problem is used to establish the goals of the project. The following session will go over the strategies used to solve this problem in detail. The results and discussion section examine the implementation of the project in depth, and are found in the last section. The result and discussion session is split into two parts: the first looks at the data, and the second looks at the implementation approach and consequences.

II. Adaptive Demand Response Management System (ADRMS)

As illustrated in Fig. 1, this project develops a two-stage hardware architecture for a multilayer Adaptive Demand Response Management System (ADRMS). A switching relay circuit couples the loads to the battery, allowing any load or source to be added or disengaged independently at any time. The system's operation is structured down into different phases, as follows.

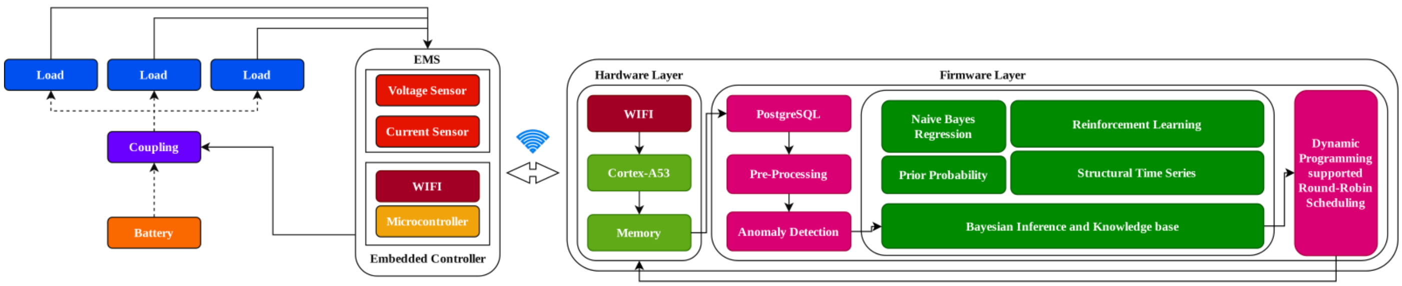

Fig. 1. Architecture of Adaptive Demand Response Management System.

Stage 1 Energy monitoring and communication: Energy monitoring module is composed of an Atmega328 microprocessor, a voltage measuring circuit based on a potential divider, an esp8266 module and an ACS712 current sensor. The energy monitoring circuit evaluates the power consumption of each load and the SOC of each battery using measured voltage and current. With the aid of a Wi-Fi module, this data is transferred to the CDPU. The CDPU is a Broadcom BCM2711 quad-core Cortex-A72 (ARM v8) 64-bit SoC with 2GB RAM and 1.5GHz single board computer. Hardware in a Loop model is used to finish the execution of operational parts.

Stage II Data storage: The data is initially saved in a PostgreSQL database using the Node-RED development tool as it reaches the CDPU. This approach is useful for analyzing real-time data.

Stage III Data Pre-processing: A large volume of data would be captured because the system will record data every millisecond. Analyzing all of this raw data would result in longer computational costs. For faster processing, the data is resampled from milliseconds to second levels. Then the data is preprocessed which involves a number of steps, including replacing missing data with local standard deviations, normalizing the data, and converting it to categorical variables.

Stage IV Anomaly with Isolation Forest (IF): Anomalies in the load curve indicate a fault or maybe a quantitative inaccuracy. Proper spotting anomalies in the load curve might help decision-making, for identifying faults and taking remedial action during forecasting. Because historical data aids in distinguishing anomaly from normal deviation, anomaly calculation is left out of the Bayesian engine. An unsupervised outlier time series analysis based on IF is used to discover anomalies. IF uses clusters of isolation trees for a given data collection, with data higher than the Euler-Mascheroni constant being deemed anomalies. When load consumption is represented as $P_L = \{P_1,.., P_n\}$, where P_{LF} and P_{RR} is the load to right and left element of tree, P_i consumption at i^{th} load, t_h is the threshold, the isolation tree is built again every time a new value is added using the equation 1 and 2. Isolation forest provides the added benefit of allowing points that cannot be isolated to be classified as normal or abnormal to be easily detected.

$$P_{LF} = P \epsilon P_n \vee P_i < t_h \tag{1}$$

$$P_{RR} = P \epsilon P_n \vee P_i \leqslant t_h \tag{2}$$

Stage V Bayesian inference and Knowledge base: The following step is to create a Bayes interference engine and knowledge base. In the comprehensive mathematical model, three distinct Bayesian oriented mathematical strategies are employed for three different applications: GNBM, BSTS, and BRL. Because the Bayes theorem governs all methods, each model undergoes numerous equivalent joint phases and processes during the operation. A polymorphism model produces a hybrid object engine that works as a centralized interference rather than adding different variables, memory assessments, and processes for each activity. Polymorphic objects are called when a common set of rules is followed, which reduces the computation cost. Independent mathematical procedures are employed in the final stages of computations. The Bayes theorem is represented as Equation 3. P(PL) is the probability of next load data and PH is the prior probability.

$$P(P_L \vee P_H) = \frac{P(P_H \vee P_L) P(P_L)}{P(P_H)} \tag{3}$$

Stage VI Gaussian Naive Bayes Model (GNBM): The load is then scheduled relying on available source capacity. As previously stated, scheduling the load based on its temporal behavior is essential for enhanced power quality, longer load longevity, higher economic sustainability, and user satisfaction. In the following phase, load is forecasted using GNBM and Bayesian Structural Time Series Analysis (BSTS). The load is forecasted in the first stage using GNBM. The probability of the load variation is predicted using equation 4.

$$P(P_L \vee P_H = \mathrm{X}) = \left(\frac{1}{\sqrt{2 * \Pi * \sigma^2}}\right) e^{\frac{-(P_L - \mu_x)^2}{(2 * \sigma^2)}} \tag{4}$$

Stage VII Bayesian Structural Time Series: BSTS is a time series interpreter that uses Bayesian criteria to choose output parameters. BSTS is based on Bayesian model averaging ensemble learning, which uses an average number of models to do stepwise regression forecasting, with the input weighting the posterior probability of each model. If Pt is the time series to be predicted, whereas αt denotes the inherent features of the load curve, Kt is a vector of coefficients for state variables, Ht is the variance with normal distribution error term with a mean of zero εt , equation 5 represents time series calculations.

$$P_t = \mathrm{K}_t^T \alpha_t + \epsilon_t \rightarrow \mathrm{for} \epsilon_t \in N(0, \mathrm{H}_t) \tag{5}$$

Now the value of α is updated with equation 6 where block diagonal transitions matrix T_t , the covariance matrix Q_t of the rectangle block R_t and each component contributes to the block with η_t.

$$\alpha_{t+1} = \mathrm{T}_t \alpha_t + \mathrm{R}_t \eta_t \rightarrow \mathrm{for} \eta_t \in N(0, \mathrm{Q}_t) \tag{6}$$

Stage VIII Bayesian Reinforcement Learning (BRL): Once the load is predicted and anomalies are handled, the following step is to allocate loads to different sources depending on the forecast value. The optimum loads for the ideal sources may be found using BRL with maximum exploitation of sources. Thompson of Sampling is a strategy to explore the progressive rewards based on the rule of Bayesian control and maximize them. The cumulative reward (R) of the load (P) is decided based on Gaussian Bayesian reward function (E) for every individual reward function μ for two consecutive stages is shown in equation 7. The system always tries to maximize the reward in a greedy manner. If the source capacity exceeds the loads, a dynamic program is integrated with BRL to locate the best resources.

$$R_t = \sum_{t=t_1}^{t_n} E\,(P_t^I - P_t) \rightarrow \max(\mu_t) \tag{7}$$

Stage IX Dynamic Preemptive Priority Round Robin (DPPRR): Following the identification of the most relevant combination using BRL, the next step is to include sources and assign loads to them. This issue is divided into two parts: the first is the source selection using dynamic programming, and the second is the source assignment using preemptive priority scheduling using Round Robin. To conserve energy, sources are only used when absolutely necessary. As a consequence, dynamic programming is utilized to choose the best sources from all available sources. Now depending on the load demand, sources are employed in a certain sequence in a time spectrum allocation using preemptive priority scheduling based Round Robin technique.

III. Results and Analysis

As shown in Table I, 49 sources were linked as a DC microgrid with a battery capacity of 20 KWH and an SPVGS of 1200 W in order to realize the idea. Table II shows the 27 distinct loads that were investigated with a maximum load capacity of 5.7 KW. In a laboratory setting, the entire technique is implemented as HIL. Due to the typical operational characteristics of the utilities grid, no automated switching is done, thus the decision making are determined using all developed models with the last step in manual switching mode.

The initial stage of execution is the assessment of source capacity and loads. At first, all batteries are charged to their maximum capacity. The next stage is to evaluate how much energy each load consumes. The load consumption is captured every millisecond and resampled to a scale of seconds by estimating the average usage each minute. The load dataset is divided into two sections: a historical segment and an instantaneous component. Instantaneous data is taken as test data, while historical data is used to train the model. When a new measurement appears, the previous instantaneous data becomes historical data. A day's worth of average load consumption data per minute is indicated in the Fig. 2. This data is used for training the model. As a result, at each point on the load curve, the data on the left is utilized for prior training and the data on the right is used for posterior learning.

Once the load statistics and source capacity have been identified, the following stage is to identify any anomalies. The system's anomalies are discovered for each load utilizing IF, and each load is graded based on the anomaly. In the last stage, this information is used as a reward during reinforcement learning as well as in priority-based queuing. Fig. 3 illustrates an anomaly over the whole training data set. Table III depicts an anomaly for a sample subset of data. Any count that is less than zero is deemed an anomaly in the table. It may be identified that even if the rate of change exceeds a particular level, it is not always deemed an anomaly because an anomaly is a function of time-dependent deviations. As such, an anomaly is defined as anything that deviates from the confidence interval, which may fluctuate over time owing to load variations.

TABLE I. Source Capacity, Type and Count

No	Type	Capacity	Number	Total
1	Li-Ion	100 WH	20	2000 WH
2	Li-Ion	250 WH	6	1500 WH
3	Li-Ion	500 WH	5	2500 WH
4	Lead Acid	1000 WH	10	10000 WH
5	Lead Acid	2000 WH	2	4000 WH
6	SPVGS	200 W	6	1200 W

TABLE II. Loads for Realization

No	Load (W)	Type	Number	Total
1	50	Fixed	5	250
2	100	Fixed	5	500
3	200	Fixed	5	1000
4	300	Variable	10	3000
5	500	Variable	2	1000

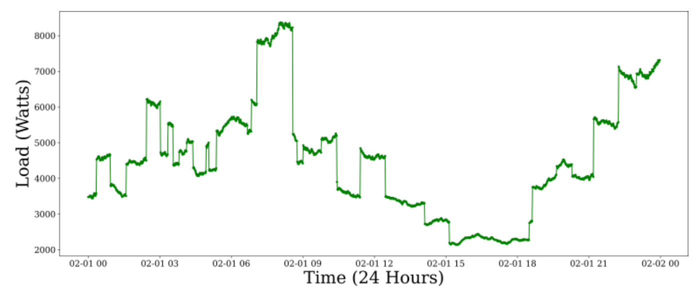

Fig. 2. Load Data for 24 Hours to be Utilized for Training.

TABLE III. Anomaly of Load Data for 12 Minutes

Time	Load (Watts)	Anomaly
1	18.94	No
2	18.95	No
3	18.83	No
4	18.89	No
5	18.88	No
6	18.94	No
7	21.09	No
8	21.03	Yes
9	20.89	Yes
10	20.95	Yes
11	20.76	Yes
12	20.80	Yes

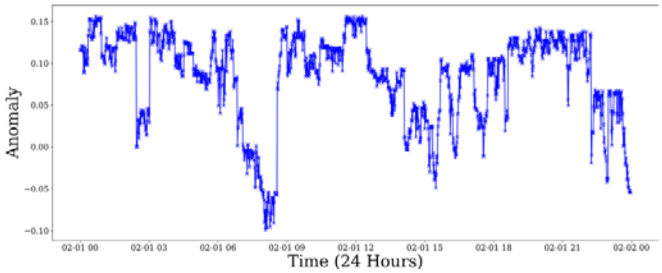

Fig. 3. Anomaly of Load Data for 24 Hours.

Furthermore, a time series analysis of the load has been presented. As previously indicated, in the short term, GNBM is used to forecast load. Two instances of GNBM based load forecasting are shown in Fig. 4 and 5. The first scenario illustrates a more accurate system, whereas the second case depicts a system with a greater RMSE. This is primarily due to the fact that GNBM is frequency dependent. In such circumstances, BSTS will be used.

BSTS is used to forecast the load with more precision, although it takes more computational cost. Fig. 6 demonstrates the load forecasting of the test data using BSTS, which is based on consecutive train-test splits. Now, each load is awarded five reward points based on anomaly, economic criteria, need, timing and magnitude, depending on the forecasted data. Based on these data, BRL is used to estimate the time allocation for each load. Table IV shows a sample of reward data for four different loads, along with the output selection time period in the last column.

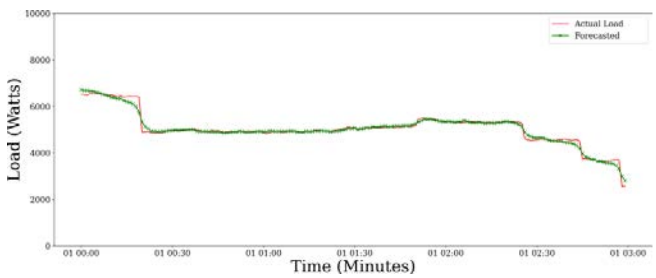

Fig. 4. GNBM based Load Forecasting.

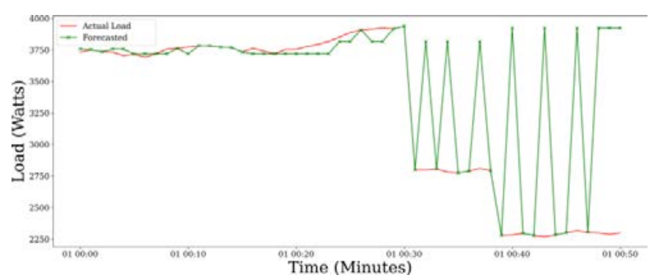

Fig. 5. GNBM based Load Forecasting – Gradient Error.

TABLE IV. REWARD BASED BAYESIAN REINFORCEMENT LEARNING

	R1	R2	R3	R4	R5	Time (Hours)
L1	2.7	6.7	0.8	2.8	1.3	3
L2	5.7	6.5	5	1.5	1.5	0
L3	7.4	2.5	2.6	4.2	1.8	2
L4	7.6	4.2	6.1	2.8	5.1	1

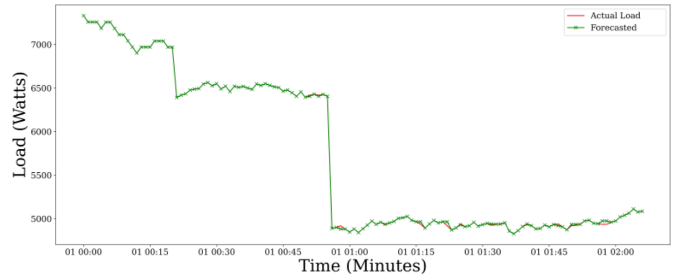

Fig. 6. BSTS based Load Forecasting.

The next step is to add sources and allocate loads to them. Dynamic programming is used to select the best sources from a large number of options. Using a Priority-based Round Robin method, sources are now employed in a certain order in a time spectrum allocation depending on load demand. The sole criterion employed to select sources is State of Capacity. Table V lists all accessible sources at instant and their capacities. Only 7 of the 10 sources with a total capacity of 477 Watts are used to satisfy a load of 331 Watts. The DPPRR based time spectrum allocation of loads is shown in Table VI.

TABLE V. SOURCE SELECTION BASED ON DYNAMIC PROGRAMMING

Source (Watts)	81	66	34	16	42	27	33	95	51	32
Total Capacity = 477 W , Load = 331 W Selected Source capacities = 66, 34,16,42,27,95,51 W										

TABLE VI. PREEMPTIVE PRIORITY ROUND ROBIN SCHEDULING

Load	Battery	Assigned Period (Hours)	Waiting time (Hours)	Execution Time (Hours)
Load 1	1	5	0	5
Load 2	1	3	5	8
Load 3	2	4	8	12
Load 4	2	7	12	19
Load 5	3	2	19	21

IV. CONCLUSION

This work developed an Adaptive Demand Response Management System (ADRMS) capable of load scheduling and load shedding using an interwoven multidimensional Bayesian inference backed by various mathematical models. The system was designed with a two-stage hardware architecture, with the first stage measuring demand and source capacity before sending the data to the second stage CDPU through LPWAN for mathematical analysis. Gaussian Naive Bayes Model (GNBM) and Bayesian Structural Time Series Analysis were employed to forecast demand. To ensure maximum precision, the two methods were used in conjunction. Bayesian Reinforcement Learning (BRL) was used to integrate demand sources based on a variety of incentives, including anomalies, cost considerations, usefulness, dependability, and size. A blended polymorphism model was developed, which decreased computation time and memory allocation while also improving operational efficiency. The Isolation Forest (IF) approach was used to identify and avoid vulnerable loads by recognizing demand anomalies. A Dynamic Programming integrated preemptive priority based Round Robin technique was used to allocate the next loads to be added.

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Determine the Main Target Audience Characteristics in M-learning Applications in Saudi Arabian University Communities

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***Abstract*—In the fourth economic revolution, which is based on digital transformation, the e-learning process represents one of the most important processes needed to deal with the revolution through increased skills and knowledge. Thus, the automation services in the e-learning field represent one of the most important and supportive means of transferring and disseminating knowledge to reach a diverse and wide segment. This study focuses on defining the parameters and characteristics of the target audience, who are interested in the e-learning method, through smart device applications in higher education institutions in Saudi Arabia. The study used a quantitative method and data collected from 539 participants from several universities and institutes to determine their characteristics. The study segment represents one of the basic aspects of and full motivations for accepting new technology; 70% of Saudi smart device users form the youth segment, which is the university age group. This is the category that is expected to have the most use of e-learning in light of the coronavirus pandemic, which has cast a shadow over the six continents of the world. This approach could help the adoption of M-learning applications by the target audience according to a number of technical and design requirements, which are presented in this study.**

Keywords*—M-learning; mobile learning; UTAUT; KSA; MOE; application quality; qualitative study

I. Introduction

E-learning represents one of the main and most important channels in the process of digital transformation, which has begun to mature in many continents and countries where e-learning represents one of the channels that helps in spreading knowledge among the various segments of society. This online process has had a great impact on the completion of the educational life march in schools and universities during the spread of the coronavirus pandemic during 2020. Through this approach, many entities were able to adopt digital transformation as a means to reduce the gap between reality and expectations during this pandemic. Many economic, commercial, and health purposes have been able to adopt digital transformation as one of the methods for reducing the impact of this pandemic that has resulted from social distancing, which is considered one of the best means of reducing the spread of the virus in societies.

There are shortfalls to be addressed in the quality of education and its opportunities for Saudi communities that require a high level of privacy and the separation of genders in education [1],[2]. According to the MOE policy in Saudi Arabia, gender segregation in education reflects the country's religious and traditional values as well as the national policy in general [3]. It is important to consider strengthening mobile learning (M-learning) approaches by determining the requirements that produce acceptable M-learning application designs for students in Saudi universities. In the meantime, more than 75% of mobile subscribers in Saudi Arabia are already using smartphone devices for most of their daily life purposes [4]. Thus, there are several opportunities that would help the target audience to more readily accept learning applications in this community. Further, the community can expand their knowledge while still maintaining the government policy associated with religious values.

Thus, M-learning applications have several requirements in their design to be more compatible and acceptable for Saudi communities. These applications would be required to promote an education policy in Saudi Arabia that is based on the separation of genders at all levels of education; at a distance, males and females can digitally exchange and share their information easily without breaking the religious restrictions of the Saudi society. Many previous studies have focused on the factors influencing M-learning's acceptance in the Kingdom of Saudi Arabia (KSA); however, there is a shortage of information concerning the main practical requirements related to particular societal or traditional elements related to the KSA community background as well as the community characteristics that could help and use the M-learning approach through the digital transformation revolution. These characteristics help to assign the main personas interested in using M-learning applications intensively, which could help with the professional application function design and analyses of the M-learning application systems in order to assess whether they are suitable and well-developed for students in higher education institutions in KSA.

Also, the policy of gender segregation in education in the KSA limits women's opportunities to fully develop their capabilities and skills, especially due to the restrictions regarding women that are based on religious values in Saudi Arabia [5]. These restrictions not only affect the flexibility of learning through the same channels provided for men but also do not allow for women to learn similar courses that would encourage them to use their knowledge with the same gender in the future [5],[6]. Some examples include restrictions around driving a car, the lack of public transportation infrastructure, and the prevention of women from traveling without permission from a male relative, such as a husband, father, or brother [7]. Some of these issues have been resolved in the last two years, but their residual influence on the Saudi community means changes will take more time to be adopted. These examples of the disparity in access to mobility have given men more chances and flexibility while delaying the same for women in KSA. These reasons lead to limitations for women in opportunities to learn similarly to men in KSA. Furthermore, many of the academic disciplines that were established recently for female students, such as industrial environmental engineering, have been available to male students for more than two decades due to several traditional considerations. However, the majority of faculty members are male, which makes learning these sciences an obstacle for female students because of the same considerations of gender segregation in the various stages of education. This affects the learning process between male teachers and female students.

This research may help students accept the potential value of an M-learning environment as a way to increase the knowledge, skills, and information sharing for the target audience and, in fact, for all potential user communities. Therefore, the expected output of this research is to determine the target audience's characteristics through M-learning as an acceptable theoretical framework to enhance their learning opportunities. The main purpose for choosing the student segment is to search for new sources for exchanging knowledge outside the formal distance-learning platform of the universities. The universities' distance learning is sponsored by the KSA government and depends on the foundations of current education policies in Saudi Arabia. Therefore, M-learning applications could be helpful for students to increase their knowledge about the subjects related to universities' courses and many other learning aspects they are interested in.

The research question is, "From an end user's perspective, what are the requirements for the acceptance of mobile learning technology for smart devices at higher education institutions in Saudi Arabia?" The end users are students studying in universities or academic institutes. In addition, this research focuses on the technological and traditional requirements needed that are important to the target audience and that will increase the acceptance level. There are sub-questions that are helpful in conducting deeper research related to the main question, specifically: How do gender, experience, and willingness influence the acceptance and use of M-learning applications in KSA? The main question identifies the importance of requirements in Saudi society, which are helpful to design the requirements for this particular society. How can these requirements be explained to increase the level of acceptance of M-learning applications for students in Saudi universities? The sub-question focuses on the unique features related to societal characteristics such as those for gender, experience, and willingness, and their influence on the level of acceptance for using M-learning applications in university students in KSA.

The research structure is divided into several parts, which are the literature review, theoretical framework, research methodology, analysis of quantitative data, discussion of results, and the implications and recommendations.

A. M-learning Definition

From a student's perspective, the essence of M-learning is the potential to learn from any location at any time using personal mobile devices [6],[8], including the support of all mobile learning methods by means of mobile computing devices or other mobile learning environments [9]-[11]. This can facilitate the educational process through mobile devices or in places where only mobile devices are available [12]. Furthermore, M-learning is a subset of e-learning, which means learning at the right time and in the right place that enables access to educational materials and communication with colleagues or with teachers at other educational institutions [13],[14]. In short, M-learning can be summed up as providing learning opportunities through mobile and handheld devices using learning applications that are compatible with smart device operating systems (OS). In addition, M-learning it can be considered as learning within one's own context in time and space [15],[16]. It is the central affordance of mobile technologies to facilitate learning, which is the key factor in any definition of M-learning.

II. Literature Review

With the wide spread of the coronavirus pandemic, digital transformation has become one of the basic aspects of many ministries that seek to benefit from providing an appropriate environment in which to activate communication channels and spread knowledge. Therefore, in the field of M-learning, we look at the importance of learning via mobile phones and the importance of learning by mobile phone in higher education in general and in academic institutions, particularly King Abdul Aziz University in Saudi Arabia.

One of the main reasons for using smart devices in the online learning field is the improvement of technologies that have appeared over the past decade [17]. This progress and achievement has contributed to reducing costs of learning compared to using desktop computers, which has led a wide range of societies to replace desktop computers with tablets or smart devices, which has further led to a steady increase in mobile device users [18],[19]. Additionally, smart devices provide many beneficial features such as cloud storage, instant access to the Internet, and continuous communication, which will help to increase their penetration and the confidence of users in their use [20].

The number of Internet users through 3G and 4G has reached more than 70% of all internet users in general, as indicated by the Communications and Information Technology Commission (CITC) in KSA [19]. This use has increased dramatically with the repercussions of the coronavirus pandemic over the past year. Therefore, there is great opportunity to benefit from the digital transformation trend by supporting mobile learning applications that are compatible with the 2030 vision of Saudi societies that serve the aspirations of the government and the people simultaneously [2]. With the limitations in the specifications of mobile devices, many of the capabilities of smart devices remain untapped due to the relatively low level of technological awareness. Therefore, mobile devices can help easily target learners and spread the mobile learning approach more widely due to the limited options on the smart device screen, which helps to spread particular information smoothly and quickly [21],[22]. Furthermore, smart devices are widely used by residents of Saudi Arabia. Therefore, students can be involved in online learning activities, and female students can be included in learning activities without any societal restrictions.

A. M-learning's Importance for Higher Education

One of the significant advantages of e-learning is the availability of many useful functions and features related to online learning, such speed in interaction and sharing of information between learners. Smart devices do not require specialized skills to use and are lightweight, are easier to use than a keyboard and mouse, and take advantage of smart features such as Bluetooth and switching between the various levels of network coverage.

The study [23] indicated eight main activities that are beneficial in the M-learning field, especially in higher education. These are sending and receiving pictures, videos, or audio files; accessing the Internet; making voice and video calls; sending and receiving emails; organizing notes; reading books; sending and receiving SMS or MMS messages; and providing learning environments without time and place restrictions [23]. These eight categories can be the main requirements for increasing the level of acceptance in M-learning applications. Moreover, the study [24] suggested that the widespread use of mobile devices on campus helps to provide multiple learning approaches and greater availability and flexibility for students [24]. Thus, the importance of M-learning in higher education will be more attractive to potential students for several reasons. Smart devices are lighter and easier to hold [25]; smart devices are becoming more acceptable compared with desktops [26]; smart devices help to increase the benefits of M-learning in the future through designed features and are built with the goal of future technological development [27]; and smart devices make a collaborative learning environment because they have social applications that can be integrated and used to share information, such as learning and teaching materials, including formative means for assessments and feedback between students and their teachers [26],[28].

III. THEORETICAL FRAMEWORK

Many studies in the field of electronic systems acceptance and adoption give priority to the requirements of the target audience and could be beneficial in increasing the level of acceptance in the M-learning fields. Therefore, many studies have provided an evaluation of the Technology Acceptance Model (TAM) focus, E-learning Acceptance Model (ELAM), and UTAUT model. The previous models presented are fundamental models in user attention and attention behavior requirements fields. These theoretical frameworks are related to the actual use and user acceptance in various field of M-learning.

A. Unified Theory of Acceptance and use of Technology

This study focuses on identifying the requirements of M-learning applications by studying the differences between the characteristic demographic groups. This could help to reach the target segment smoothly and easily. Additionally, this study searches for new development aspects in M-learning, particularly in an in-depth manner through theoretical frameworks that focus on consumer behavior.

UTAUT was developed by [29] by combining the characteristics of many previous theoretical frameworks, for example TAM, ELAM, & DOI, which focus on product characteristics and the characteristics of the target segment (see Fig. 1). Furthermore, UTAUT focuses on studying the differences between the poles of the target segment by applying moderators to understand the characteristics of the target segment. The moderators that were applied in this study were gender - experience - voluntary, which represents a direct impact on the acceptance and approval of electronic systems [29]. A number of studies have also indicated they eliminated some moderators who did not show the common differences between both sides, whereas the study [25] indicated that the age vector has been dispensed of, as students at the university have a similar age group between 22 to 30 years. Therefore, this age group has great common characteristics, which means that their interests are common and similar to some extent.

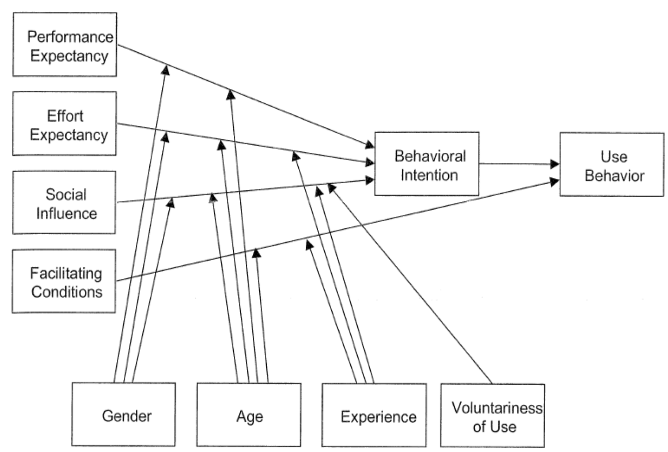

Fig. 1. The Unified Theory of Acceptance and use of Technology (UTAUT) Model.

As in study [20], it is important in bridging a gap in the analysis of gender and age as factors in M-learning technology acceptance. In particular, it was demonstrated that age differences moderate the impact of social influence and effort expectancy on M-learning using intention [20]. That is, for older mobile learners, a high effort expectancy and social influence may play a greater role in the acceptance of M-learning. Additionally, it was established that gender differences moderate the impact of self-management on learning and of social influence on M-learning acceptance. In particular, the study demonstrated that social influence is "…a stronger predictor of behavioural intention for men than for women" and "…self-management of learning influences behavioural intention more strongly for women than for men" [20]. The authors hypothesized that the lesser impact of social influence on women may possibly be explained by "…women being more unfamiliar with relatively advanced and complex M-learning technology, making them less likely to be influenced by their close friends in the early stages of M-learning development" [20]. Although this hypothesis seems plausible, one must take the cultural and national context of M-learning acceptance into account, as that study was conducted among Taiwanese students (330 respondents), who may differ from their Western peers.

The study [30] investigated the factors that influence students' intention to use M-learning. They tested and validated a model based on the UTAUT using a sample of students from the University of Technology Malaysia and analysed their quantitative data using the Statistical Package for the Social Sciences (SPSS). Briefly, [30] sought to derive a completely new model to explain or conceptualize M-learning. They began by arguing that M-learning has the potential to significantly enrich the education sector by putting educational content in the hands of all students without regard to their location. Their study concluded that M-learning is independent of the geographical location of both the learner and the instructor, and the former can learn continuously from any place. Thus, the authors set out to develop an integrated model that investigated the predictors of behavioral intention by university students to make use of M-learning. The main constructs used in this study were the self-management of learning and perceived usefulness. Both constructs have been deemed to be quite important determinants and predictors of behavior. Voluntariness of use has been added as a possible influencing factor on the behavioral intention to use M-learning [30].

The author in [25] also used UTAUT as a starting point from which to investigate the factors influencing M-learning acceptance among students. In particular, their study extended the UTAUT to include such variables as the quality of service, personal innovativeness, and the social influence of lecturers, which replaced the "facilitating conditions" factor of the initial UTAUT framework. To test the impact of these variables as well as the performance expectancy, effort expectancy, and lecturers' influence, [25] conducted a survey of 174 participants from Brunei University. They excluded the age and gender moderators of the UTAUT framework, as the majority of the sample selected was made up of males of roughly the same age. Students' prior experience with mobile technologies was selected as a key moderator in shaping their acceptance of M-learning. The study revealed that all factors and moderators had a significant impact on M-learning acceptance among Brunei University students. Effort expectancy was found to be the strongest predictor of students' intention to use M-learning [25]. However, the authors acknowledged that the validity of these findings was limited in several respects. The limitations were the non-inclusion of actual M-learning usage in the research process and the potential bias of the sampling method (non-inclusion of female and elderly participants) [25].

B. *Framework of M-learning Acceptance in Saudi Arabia*

Following the examples provided by the reviewed studies, the current research uses the UTAUT framework as a starting point for the M-learning acceptance analysis. This framework was positively assessed by various researchers and was determined to provide an integrated vision of technology acceptance by exploiting the cumulative insights of other widely used frameworks [22],[25]. In addition, the UTAUT framework includes various moderating variables, such as age and gender that are central to understanding how the various technology acceptance factors may translate into the intention to use a given technology.

Notwithstanding its benefits, however, the UTAUT framework would also benefit from being adjusted to the specific context of M-learning technologies. Various studies discussed in the literature review have used adaptations of the UTAUT model, which include additional factors as perceived playfulness, personal innovativeness, attainment value, quality of service, and self-management of learning and self-efficacy, among others [20],[25],[30],[31]-[33]. Proceeding from the critical analysis of these contributions offered in previous parts, the present study next advances an extended UTAUT framework that includes the following parameters. Each parameter is defined according to the objectives of this study.

- Performance Expectancy: Personal belief in whether a type of information technology can contribute to educational and professional performance and/or success.
- Effort Expectancy: Attitude towards the effort (knowledge, information, and time) required to master a particular information technology.
- Lecturers' Influence: The extent to which a person believes in the importance of others' attitudes towards his/her usage of a given technology.
- Personal Innovativeness: A measure of a person's creativity and willingness to try out any new kind of information technology.
- Application Quality: The quality is defined as value that promotes satisfaction, appropriate use, and ultimately positive effects on the individual or organization, and thus affects the application's capabilities and positive impact on user satisfaction. Fig. 2 outlines mobile application quality as a standalone factor in the model. It should be noted here that this term is made of three secondary factors that measure mobile application quality. As we wanted to measure individual responses to different aspects of quality, we chose the broad heading of mobile application quality and derived three measures from the systems quality literature discussed above.
- Behavioral Intention: One's behavioral disposition towards the use of an information technology as affected by the above factors.

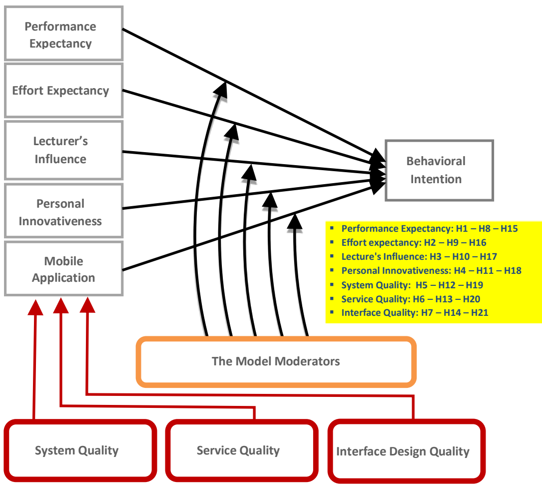

Fig. 2. The UTAUT (Modified) Model for Successful M-learning Application.

The proposed model utilizes three factors formulated in the initial UTAUT framework: effort expectancy, behavioral intention, and performance expectancy, as well as a modified "social influence" variable emphasizing the lecturers' influence in M-learning acceptance. Additionally, the framework extends the UTAUT to include personal innovativeness, which we consider to be important in understanding the M-learning context. In particular, personal innovativeness refers to an individual's willingness to acquire a creative experience with new information technology and also his or her ambition to develop personal creative capacities. The inclusion of personal innovativeness in the framework was motivated by the available evidence of its role in technology acceptance. In particular, the IDT framework suggests that innovative individuals are attracted to positive ideas and changes in technology and have higher levels of uncertainty tolerance [34]. Similarly, the [25] hypothesized that those students with high levels of personal innovativeness "would be more risk taking and have a more positive intention to use M-learning in their study" (p. 91). Also, mobile application quality concentrates on the quality assessment, which drives an increase in M-learning's acceptance level by students, as mentioned in detail in other previous parts of this research [7].

C. *The Theoretical Framework for this Study*

The proposed framework alters a set of UTAUT moderators by including gender, experience, and voluntary use. The age moderator was excluded because the proposed framework was tested on students from a similar age group from 19 and 25 years of age. The "voluntariness of use" moderator was divided into high and low levels of voluntariness, because the framework will be applied to regular M-learning courses at Saudi public universities but will be optional for online or on campus courses. The experience moderator was divided into two groups: a high level of experience (more than three years) and a low level of experience (three years or less). Similarly, the gender moderator was divided into two groups (female and male).

D. *Summary of the Research Model Measurements*

As presented in Section 2.7, the measurements used in this study are as follows:

Performance Expectancy (PE)

1. PE1: M-learning must be useful for the students' studies.
2. PE2: Using the M-learning applications should enable students to achieve learning tasks more quickly.
3. PE3: The use of M-learning in students' studies should increase their learning productivity.
4. PE4: M-learning applications should improve the users' collaboration with other classmates.
5. PE5: Using M-learning applications may gradually improve students' academic performance.
6. PE6: M-learning applications have clear educational goals.

Effort Expectancy (EE)

1. EE1: The M-learning application should be a flexible system that is easy to use.
2. EE2: Multimedia files should be provided to help users operate an M-learning system.
3. EE3: Clear and understandable instructions that let the user interact with M-learning application should be available.
4. EE4: The learning features of the M-learning applications should be easy to use.

Lecturer's Influence (LI)

1. LI1: I would use an M-learning application more if it were recommended by academic lecturers.
2. LI2: The M-learning application would be used if there were technical and academic support channels.

Personal Innovativeness (PInn)

1. PInn1: New M-learning applications and technology can be used without any reservations.
2. PInn2: It is important to provide the online educational resources for learning through smart devices.

Mobile Application Quality (MQ)

System Quality (MQSY)

1. MQSY1: Sufficient processing time is allowed to determine the actual courses or relevant material.
2. MQSY2: An advanced search mechanism in M-learning application is provided.
3. MQSY3: An adequate response time is allowed to download and launch the learning material on smartphone devices.
4. MQSY4: M-learning applications are able to support different languages.
5. MQSY5: Features that give M-learning applications the ability to support learners and tutors with different learning needs are offered.

6. MQSY6: The M-learning application has understandable language and is free from grammatical and syntactical errors.
7. MQSY7. The M-learning application is easy to find and install in any given device or system.

Service Quality (MQSE)

1. MQSE1: It is important that the content of the M-learning application systems is of high quality.
2. MQSE2: From a security perspective, the M-learning application systems are secure and keep confidential information in a safe place on the devices or in the application.
3. MQSE3: Providing a mechanism for updating information periodically is important.
4. MQSE4: Users can easily handle mobile devices and applications.

Interface Quality (MQIN)

1. MQIN1: The design of M-learning applications has to be in comfortable colors and fonts in the applications to be used.
2. MQIN2: A short menu and shortcut buttons should be included to allow users to easily access the application's main functions.
3. MQIN3: The functions required by individual users are provided.
4. MQIN4: M-learning applications should provide a drop-down menu for the most frequently used links.

Behavioral Intention (BI)

1. BI1: I use M-learning applications in my studies regularly.
2. BI2: I predict that I will use M-learning applications frequently.
3. BI3: I intend to increase my use of mobile services in the future.
4. BI4: I will enjoy using M-learning applications due to the appropriate features of this system.
5. BI5: I would recommend M-learning systems to others.

E. *Moderator Hypotheses*

The hypotheses related to the moderators measure the impact and the significant relationship of these moderators to the main constructs in the theoretical framework. A number of previous studies have indicated that individuals may have different characteristics because of their gender, experience, and level of voluntariness, which are the main moderators in UTAUT. The potential moderator of the age group was ignored because the sample is fairly homogenous in terms of age.

Some researchers have supported the concept that the expected effort will be a stronger determinant of women's individual intentions (e.g., [29], [35]). Also in study [20] and [36] noted the difference between women's behavioral intention in using M-learning and in using smart devices. Therefore, it is expected that students' acceptance of M-learning via smart devices depends on the ease of use as well as societal characteristics based on the differences in moderator variables, which are divided into three sections: gender, experience, and level of voluntariness. Thus, the five hypotheses will be applied separately with each moderator, as presented in Appendix B.

IV. Methodology

This study sample was of students from the universities who have an existing infrastructure of distance learning in Saudi universities. Before the COVID-19 pandemic, the main three universities that had a distance learning sector and relevant magnificent structure were King Abdul Aziz University (KAU), Saudi Electronic University (SEU), and King Faisal University (KFU). The students at these universities were helpful to the research team because of their previous experience [37]-[39]. The availability of distance learning facilities at these universities was helpful in determining the main requirements for M-learning applications that might be beneficial to increasing these applications' level of acceptance.

The questionnaire was distributed to undergraduate students based on email lists supplied by the Office of the Deans of Information Technology at these universities. Other potential participants were selected from social networks such as Twitter, Facebook, and LinkedIn using the "snowballing" technique. This technique is useful in Saudi Arabia because willingness to participate is likely to be increased by receiving the invitation from a known person. The following conditional questions were used to filter participants who qualified as the main targets of this study:

- Have you ever used E-learning systems before?
- Do you use smartphone devices?
- Are you a resident of Saudi Arabia?
- Are you a higher education student? If yes, please enter your age (…………) and your degree program (Diploma/Bachelor/Master/PhD).

Positive answers to all of these questions qualified the participant for the survey and vice versa.

A. *Data Analysis and Main Findings: Demographic Questions*

The demographic questions are categorized into three main groups. The first group determines the participants' basic characteristics (Q1 to Q3) and focuses on participants' genders, ages, and educational levels. The second group concentrates on the characteristics of learning through M-learning applications (Q4 to Q6) and focuses on their previous experience with smart devices, level of knowledge regarding E-learning, and frequency of learning via electronic channels. The last group of questions focuses on the characteristics of working on smart M-learning devices (Q7 to Q11). This last group includes a focus on the type of internet service provided, the type of operating system used, the type of smartphone used in general, and the type of learning process adopted in particular. Appendix 1 summarizes the result of the demographic survey.

The results showed many principal points required focus. With respect to the first group of questions, both the male and female participants (46.2% and 53.62%, respectively) generally exhibited interest in online learning through smartphone applications. This finding is attributed to the spread of these devices in the Arabic region, particularly in Saudi Arabia. The responses to the second question indicated that, among the university students expressing considerable interest in online learning, 54% were studying for undergraduate degree programs and 45.09% were studying under master's or doctorate degree programs. This question was also intended to determine whether the bachelor's, master's, and doctorate students were aged between 18 and 30.

The second group of demographic questions highlighted three ideas of interest related in this study. First, measuring previous knowledge of dealing with smartphone applications was facilitated by experience with electronic applications in general and M-learning in particular. The findings showed that 36.18% of the students used M-learning applications for more than five years and that 58.45% had experience of between one and four years. Among the participants, 75.51% stated they had a good level of experience with applications and learning through mobile applications, which helped determine the main acceptance requirements of the target segment. The responses to Q4 and Q5 indicated that the experience and knowledge of the target segment were fairly high (42.49% and 36.18%, respectively). The responses to Q6, which focused on the participants' willingness to use M-learning applications through smart devices and their levels of preparation for such endeavor, reflected equality among the participants (High - Low) in terms of willingness.

In the third group of demographic questions, the responses to Q7 showed that 62.71% of the participants used the Internet daily. These results reflected the variety of options available for internet access and indicated that a larger segment of the sample preferred postpaid and DSL services, given the appeal of these offerings to the youth in Saudi Arabia. As shown in the responses to Q9, 3G users accounted for over 59.74% of the sample, whereas the 4G users did not exceed 25.23%, showing that fewer areas in Saudi cities and in the countryside are ready to provide 4G services by ISPs. Among the participants, 13.54% or less accessed Wi-Fi services. The responses to Q10 showed that 69.2% of the respondents used smartphones to connect to the Internet, supporting the importance of developing and implementing innovations that are compatible with M-learning smartphone applications. As shown in the responses to Q11, the participants regarded smartphones, iPads and tablets, ultra-laptops, and palmtop PCs as the most important devices used in online learning, with percentages being 92.95%, 67.72%, 79.41%, and 42.12%, respectively.

B. *Testing the Moderator Hypotheses*

A number of previous studies have delved into theoretical acceptance models, such as the UTAUT dealing with electronic system acceptance and consumer behavior, which is generally one of the fundamental aspects of increasing levels of technological acceptance [29]. One of the main reasons for establishing moderators in the UTAUT model is the need to probe into the influence of moderators on the acceptance and use of electronic systems and the effects of traditional communities on such reception and adoption. According to study [25], different moderators influence the acceptance of technological systems. The use of moderators is an important approach to dealing with theoretical models that are grounded in the unique characteristics of specific communities.

In the relevant previous study, the basic analytical requirements, which centered on the reliability and stability of the theoretical framework were completed. The current study, the acceptance of M-learning through smartphones among Saudi higher education students, was illuminated on the basis of three moderators: gender, level of experience, and extent of willingness. The data was divided into two groups for each moderator. That is, gender was classified into male and female; level of experience was divided into high, which corresponds to more than three years, and low, which is equivalent to less than three years; and the extent of willingness was divided into high and low levels. The number of moderators by group is presented in Table I.

TABLE I. NUMBER OF RESEARCH MODERATORS BY GROUP

Moderator	**Group Level**	**Sample Distribution by Moderator Group**	
		N	**P**
Gender	**Male**	250	46.38%
	Female	289	53.62%
Experience	**High**	254	47.12%
	Low	285	52.88%
Voluntariness of Use	**High**	295	54.74%
	Low	244	45.27%

The purposes of these moderators were to identify the differences among the participants and determine the characteristics of acceptance of M-learning applications on the basis of the acceptance requirements identified in this study. Correlation coefficients, critical ratios, and p-values were used for each construct to pinpoint the differences in relationships between the constructs. The chi square ($\chi 2$) and degree of freedom (df) were likewise necessary in calculating the differences among the groups of moderators. Computing the path of differences among the moderator groups necessitated calculating all the 21 hypothesized paths (gender - experience - willingness) to determine any significant path in the model. Then, insignificant paths were removed, and effective paths were retained in the moderator groups. Subsequently, the $\chi 2$ and df of the constrained and unconstrained models were calculated to determine the level of change in the groups' model Δ $(df = 1)$ and to identify significant paths [40].

The grouping of the participants was determined according to the division of the theoretical model's moderators. The males accounted for 46.38% of the sample, and the females accounted for 53.62% (see Table II). The relationships between the constructs on the basis of gender were PE → BI - EE → BI - LI → BI - PInn → BI - MQSY → BI - MQSE → BI - MQIN → BI, all of which were significant, except for LI → BI - PInn → BI. This means that the gender moderator reflected high interest among Saudi university students in learning through M-learning applications. The constrained and unconstrained tests indicated a significant difference between the males and females and significant relationships between BI and PE, EE, MQSY, MQSE, and MQIN in both the male and female groups.

Experience was treated as a principal moderator because it is a key driver of the acceptance and use of M-learning applications. Among the participants, 47.12% and 52.88% had high and low experience with M-learning applications, respectively. The relationships reflected based on the experience moderator were similar to those demonstrated based on the gender moderator. LI → BI and PInn → BI had no significant relationship with respect to experience, but the other hypothesized relationships were significant among the respondents with high and low experience.

TABLE II. SUMMARY OF PATH COEFFICIENTS, T-VALUES AND P-VALUES FOR GENDER AND EXPERIENCE MODERATORS

Gender		Male, N= 250, 46.38%			Female, N= 289, 53.62%			Constrained model		Unconstrained model		Δ (df =1)	Testing result
		Estimate	t-value	P	Estimate	t-value	P	$\chi2$	df	$\chi2$	df		
H1	PE → BI	0.573	5.829	***	0.629	6.498	***	3455.3	57	3450.9	51	4.4	Supported
H2	EE → BI	0.626	4.998	***	0.701	6.209	***	3227.8	55	3221.2	50	6.6	Supported
H3	LI → BI	0.637	6.422	.123	0.503	7.193	***						N.S
H4	Plnn → BI	0.765	5.760	***	0.601	5.238	.142						N.S
H5	MQSY → BI	0.684	6.343	***	0.660	7.326	***	3460.8	59	3449.9	53	10.9	Supported
H6	MQSE → BI	0.505	6.116	***	0.561	7.002	***	3170.8	58	3159.9	54	10.9	Supported
H7	MQIN → BI	0.655	5.571	***	0.741	6.935	***	3256.8	60	3243.9	55	12.9	Supported
Experience		High – more than four years, N= 254, 47.12%			Low – Less than four years, N= 285, 52.88%			Constrained model		Unconstrained model		Δ (df =1)	Testing Result
		Estimate	t-value	P	Estimate	t-value	P	$\chi2$	df	$\chi2$	df		
H8	PE → BI	0.611	6.133	***	0.589	6.294	***	3479.7	51	3473.3	49	6.4	Supported
H9	EE → BI	0.513	4.655	***	0.600	6.421	***	3339.7	52	3323.3	48	16.4	Supported
H10	LI → BI	0.661	7.297	.234	0.607	6.697	***						N.S
H11	Plnn → BI	0.694	7.237	***	0.622	4.687	.412						N.S
H12	MQSY → BI	0.551	6.924	***	0.606	7.180	***	3361.5	50	3353.3	49	8.2	Supported
H13	MQSE → BI	0.622	7.051	***	0.697	6.798	***	3430.3	49	3422.3	50	8	Supported
H14	MQIN → BI	0.531	6.332	***	0.587	6.751	***	3485.12	51	3475.1	51	10.02	Supported
Willingness to Use		High – more than four years, N= 295, 54.74%			Low – Less than four years, N= 244, 45.27%			Constrained model		Unconstrained model		Δ (df =1)	Testing Result
		Estimate	t-value	P	Estimate	t-value	P	$\chi2$	df	$\chi2$	df		
H15	PE → BI	0.689	6.414	.163	0.525	5.988	.127						N.S
H16	EE → BI	0.543	5.559	***	0.691	5.693	.151						N.S
H17	LI → BI	0.660	7.059	.265	0.587	6.583	***						N.S
H18	Plnn → BI	0.590	5.218	***	0.668	5.646	***	3089.822	52	3089.492	51	0.33	N.S
H19	MQSY → BI	0.596	6.951	***	0.553	6.687	***	3090.822	54	3082.492	50	8.33	Supported
H20	MQSE → BI	0.615	6.881	***	0.558	6.279	***	3060.822	52	3055.492	53	5.33	Supported
H21	MQIN → BI	0.582	6.414	***	0.628	6.231	***	3087.822	49	3084.492	57	3.33	Supported
Notes: PE = Performance Expectancy, EE = Effort Expectancy, LI = Lecturers' Influence, PInn = Personal Innovativeness, MQSY = System Quality, MQSE = Service Quality, MQIN = Interface Quality, BI = Behavioural Intention; - *p < 0.1, **p < 0.05, ***p < 0.001													

Willingness to learn through M-learning applications is an equally important aspect of technological acceptance. The use of learning techniques to enrich and spread education is paramount, because the users have all the fundamental requirements that they need to learn through M-learning applications. This is expected to increase willingness and interesting opportunities to learn through educational applications. Out of the participants, 54.74% and 45.27% exhibited high and low willingness, respectively. The relationships PE → BI, EE → BI and LI → BI were nonsignificant with respect to both high and low willingness, but the other hypothesized relationships were significant (see Table II). The relationship PInn → BI was insignificant under the $\Delta\, \boldsymbol{df}$ computation; thus, this relationship was eliminated because of its insignificance. The relationship MQSY → BI - MQSE → BI - MQIN → BI was significant for those with both high and low willingness. As shown in Table II, most of the hypothesized paths for the gender, experience, and willingness moderators were important and significant with respect to the sample. MQSY, MQSE, and MQIN were also significant under both divisions of each of the three moderators.

V. Discussion

There are two main questions associated with the current research. Therefore, M-learning applications can be implemented in accordance with various supportive functions and user features in KSA society, and the main difference between the two sides of the target audience moderators can be determined.

How can M-learning applications be appropriately implemented in accordance with the technical support, awareness and knowledge, and tools and features connection functions in KSA?

This section clarifies and combines the main M-learning requirements that are important for the target audience of this study. The questions presented for some these requirements were mentioned in the open-ended questions in the survey. These requirements are presented in detail in Fig. 3, which focuses on the various difficulties encountered by users.

The requirements were categorized into three groups. The first is technical support, which pertains to the development of tools that support users and the manner in which appropriate solutions to problems are formulated. The second is awareness and knowledge, which centers on the presentation of information and features that users need to motivate their engagement with M-learning applications. The third concerns the tools and features connection, which revolves around the tools, capabilities, and features that hasten the evolution of the M-learning process and the full connection of applications with users. The first and second groups are critical in increasing M-learning acceptance and use, and the third attaches credibility to such applications and ensures their availability for use by the target segments. Although the third group is regarded only as moderately valuable, it is still important to provide a way to link consumers and M-learning applications. The viewpoints shared by the participants were consolidated to enable the management of the requirements related to each group. The consolidation resulted in eight elements, as listed in Table III.

As previously stated, the open-ended questions were intended to gain a broad picture of the developmental requirements for M-learning applications from the target audience. Identifying issues and proposing appropriate solutions based on students' perspectives may determine what application features are suitable for this population. The participants proposed several services for supporting and connecting content in M-learning applications for instructors, developers, and students (as presented in Fig. 3).

TABLE III. M-Learning Application Requirements from Both the Students' and Developers' Perspectives

No.	Requirements	Related Group
1.	Provide online support services for operating and activating M-learning applications through discussions with an experienced team.	Technical Support
2.	Provide basic information that a user needs to run an application (instructions).	Awareness & Knowledge
3.	Provide basic information that explains the advantages and features of M-learning applications.	
4.	Implement regulations and policies for education in general and M-learning in particular.	
5.	Clarify rights and responsibilities, including those related to safety and privacy, in dealing with M-learning applications.	
6.	Provide information and explanations that increase the acceptance of M-learning applications and the confidence in using them.	
7.	Provide data storage methods, whether these are in-device features or external repositories, such as servers or cloud platforms.	Tools & Features Connection
8.	Ensure the availability and reliability of an electronic presence across different channels of communication for the servicing of E-learning and M-learning needs.	

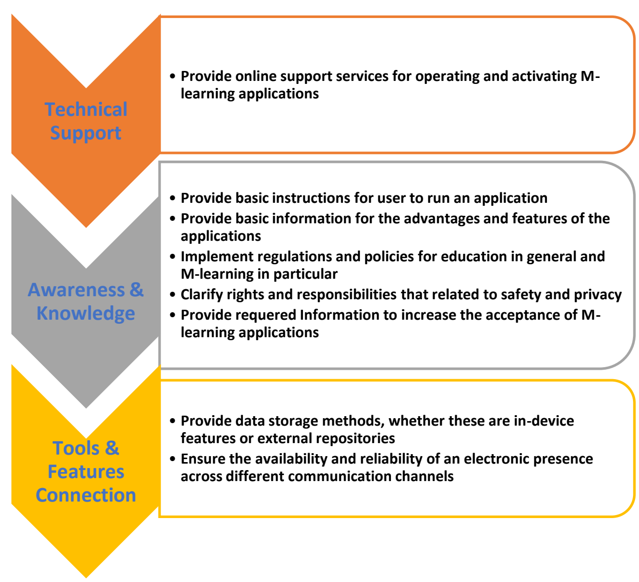

Fig. 3. M-Learning Application Requirements from both the Students' and Developers' Perspectives.

How do gender, experience, and willingness influence the acceptance and use of M-learning applications in KSA?

A. *Effects of Gender*

The gender moderator significantly affects the relationship between BI and the other constructs (PE, EE, MQSY, MQSE, MQIN) and plays a key role in moderating M-learning acceptance in relation to the aforementioned constructs. The results on the hypotheses related to gender are positive, confirming that females are more strongly affected by M-learning applications than are males, but the first test on the hypotheses generated empirical evidence that both genders have a strong relationship with the use of M-learning applications (see Table II). The respondents specified the effort that they expect to exert in dealing with various learning stages and expressed the belief that they can accomplish their online learning missions through M-learning applications.

This accomplishment can be included as a core expectation from users given that online learning through smart devices reduces the effort and time required to complete learning tasks and reflects academic performance as accurately as possible [36],[41]. Effort is a concern of the target users, and the statistical results indicated that expected effort is significantly associated with both genders. Both the male and female participants recognized the importance of expected effort in relation to many different aspects of online learning. Examples of these aspects are high flexibility in learning through M-learning applications, the availability of multimedia and assistive instructions, and the highlighting of features that help elevate learning on these applications [42]. As expected effort facilitates a thorough engagement with applications, providing online learning resources and other features and tools may increase such engagement, acceptance, and reuse in various disciplines and for various purposes [42],[43].

Generally, both genders moderated the relationship between LI and PInn and the relationship between LI and BI, and no difference existed between males and females as to this moderation [44]. The aforementioned relationships are therefore of a normal nature.

Quality requirements are viewed as an important component because MQ is significantly related to both genders in terms of the public relations ideas expressed in H5, H6, and H7. However, this level of importance is greater among women than men in the gender moderator tests, supporting the earlier consideration of providing equal educational opportunities for women in Saudi Arabia [36],[45]. Saudi family orientations and community traditions dictate that women stay at home rather than venture outside, unlike Western women, and Saudi females serve inside the houses more often than do Saudi males. Gender segregation in formal education also denies women many educational opportunities [3]. The results on gender pointed to the need for fairness in education for Saudi women—a goal that can be achieved through the provision of education via various electronic services, including M-learning [badwelan].

Females ascribed significant importance to using the M-learning applications compared with males, as evidenced by the difference between the constrained and unconstrained model tests (see Table II). That is, it is more important to determine women's requirements than those of men because, despite the value of establishing a framework commensurate with the desires of both genders, females are the main target group for the acceptance and use of M-learning applications [36],[45]. Nevertheless, these results should encourage interested private sector companies in Saudi Arabia to continue developing and designing features that fit the requirements of both men and women as the findings on gender as a moderator confirmed that both groups strongly wish to accept and use M-learning applications.

B. *Effects of Experience*

As stated in [29], the experiential impact of electronic applications is one of the most important moderators of BI. In the current research, the experience of dealing with smart device applications is an equally vital mediator of the relationships between PE, EE, LI, PInn, MQSY, MQSE, and MQIN as the core constructs and BI as the target construct (see Table II). The experience moderator measures the experience that builds upon high and frequent demand for the use of an information space through smart devices and internet connectivity [46]. The results indicated that actual and high access to the Internet through smart devices, laptops, or desktops markedly increases the usage of smart device applications [19]. High engagement with the Internet means users would be considerably proficient in identifying the features that would elevate their acceptance of M-learning applications [29],[47]. The findings also demonstrated that previous experience helps attract highly proficient internet users. PE, EE, MQSY, MQSE, and MQIN thus have a significant relationship with the behavioral intention to use easy and/or complex M-learning applications, which explains why more comprehensive encounters with such innovations increases their acceptance.

The results regarding H8, H9, H12, H13, and H14 support the principal function of internet usage in increased acceptance. Many examples in the literature on the smartphone context corroborated the proposition that dealing with smart device applications helps augment the chances that they will be adopted by university students. The results of the present research are therefore consistent with those of a number of previous studies, including [29],[34],[35].

C. *Effects of Willingness*

Willingness was another key moderator used to measure the acceptance and use of smart device applications. Voluntary usage, instead of compulsory adoption, facilitates the patronage of technology and many different electronic systems [28]. Willingness can be employed to measure user awareness of how to deal with M-learning applications, what their advantages are and how to obtain information that can persuade users of the benefits of their use [2]. The results on willingness showed that this moderator is significantly related to system, service, and interface quality, as proposed in H19, H20, and H21. Quality exerts a positive impact on increasing willingness and, hence, the BI and actual use by target users in the future [26],[48]. The availability of various quality features elevates willingness, as suggested in the positive results for the aforementioned hypotheses [49]. The difference between increases in users' engagement with educational applications may be attributed to the availability of these quality features. The statistical findings are consistent with those of previous studies (e.g., [2],[25],[28],[50]).

VI. Implications

Apart from the UTAUT framework-based identification of requirements, other research questions contributed to pinpointing many other needs related to increasing awareness and knowledge of the use of M-learning applications. There are some implications related to this study that are summarized in the following parts.

1) Technical support for learning applications: The study discovered a weakness in the technical support for M-learning applications, making this one of the main obstacles to their acceptance and adoption [36],[45],[51]. The most reliable way to deal with technical service problems is to effectively provide technical support. Even though technical support failures may be minor, these may rapidly reduce the appeal of electronic systems to target users [56]. Therefore, a highly qualified technical support team should be tasked with quickly detecting and responding to technical problems or user requests. Responses to target users' queries should be highly efficient, and support teams should be able to demonstrate how online learning tools are used.

"Technical support" should also be defined to determine what functions can be covered under this term [36], [51]. The author in [52] described technical support as the "information that helps users of computer solutions to be outstanding, whether in hardware or software." Technical support can thus mean a help desk, an information center, an online communication channel, a telephone call system, an email response system, and other similar facilities. The study [36] emphasized that technical support requirements are key points that may increase the acceptance of M-learning applications in smartphones.

2) Lack of awareness of e-government services: The study also identified a lack of awareness and information about online learning services, and this requirement ranks second to technical support as a fundamental and important component [53]. The availability of comprehensive information may increase awareness of M-learning applications and their usage [36]. The information needed by target users differs depending on the traditions and abilities of communities. The information required by Saudi university students to raise their awareness and knowledge of M-learning centers on five key aspects.

Firstly, this population requires basic information on operating online learning applications. Secondly, they need information that improves their understanding of the features and services available in M-learning applications. Thirdly, they require accurate policies and regulations for learning and E-learning. Fourthly, the rights and responsibilities of users and developers of M-learning applications should be clarified and concentrate on safety and privacy. Finally, they need clarifications that help them run M-learning applications more professionally and thereby increase their acceptance and confidence in dealing with these technologies [45],[51].

Providing the many types of information users need for understandability increases the possibility of use and the BI to engage with these online learning applications in the student communities of Saudi universities [53]. In addition, students can be persuaded to use M-learning applications through promotions and advertisements in social networking sites, which are frequently visited by university students, or through discount cards for subscriptions to the educational materials available on smartphone applications [2]. Previous studies have demonstrated that there are generally many ways to raise awareness of any new technology or service and support its use [2],[43],[54].

3) Availability and reliability of internet connection: The availability of high-speed internet services may inspire community acceptance and usage of M-learning. High-speed internet enables users to download basic information and resources via applications, making such connectivity a feature that most reliably motivates engagement with M-learning applications [55]. Naturally, slow internet speeds negatively affect the operation of electronic applications and reduce users' motivation to use M-learning technologies [47].

One of the key reasons for poor connectivity in Saudi Arabia is the implementation of filters and firewalls for secure internet access; this regulation is overseen by the Communications and Information Technology Commission, and it means that access to information resources is slower in Saudi Arabia than in countries that do not have such a filter system for internet resources [56].

High-speed connectivity increases the motivation of target users to try out the various features of M-learning applications and reduces the effort needed to engage with electronic systems or the time spent accessing informational resources [47]. Connecting to the Internet can also shorten certain tasks that usually take considerable effort and time through traditional learning methods (e.g., visiting universities or academic centers in person to obtain information versus acquiring the same information by navigating the resources included in online learning applications).

VII. Conclusion

This study focused on determining the target audience's main characteristics that could be helpful in activating a digital transformation through M-learning methods in smart phones. This approach defined the target segment in Saudi universities, a large segment, for using smart phones in Saudi Arabia, along with most internet users through smart phones. Therefore, automation services in M-learning represent one of the most important means supporting the transfer and dissemination of knowledge. This study focused on identifying the number of basic requirements related to different groups of moderators (Technical Support - Awareness & Knowledge - Tools & Features of Connection). One of the main benefits for studying the target audience characteristics is spreading the M-learning approach through smart devices in higher education institutions and universities in Saudi Arabia to support the Saudi 2030 vision through applying the digital transformation solution in various aspects of life. The quantitative method was used to determine these characteristics, which are expected to have the greatest effort throughout the coronavirus pandemic, as this approach is expected to help to with adoption of M-learning applications by the target audience according to the number of technical and design requirements contained in this study.

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APPENDIX A: (DESCRIPTIVE RESULT OF DEMOGRAPHIC QUESTIONS)

Results of Demographic Questions (N = 539)		
Category of Participants	No.	%
Q1. Gender		
Male	289	53.62
Female	249	46.2
Missing	1	0.19
Q2. Age Group		
18 Years or Less	12	2.23
19 – 20	38	7.05
21 – 22	92	17.07
23 – 24	105	19.48
25 – 26	93	17.25
27 – 28	67	12.43
29 – 30	61	11.32
31 Years or More	66	12.24
Missing	5	0.93
Q3. Level of Education		
Undergraduate	70	12.99
Graduate	221	41
Master	202	37.48
PhD	41	7.61
Missing	5	0.93
Q4. Experience with Smartphones		

Less than 1 year	22	4.08
1-2 Years	86	15.96
3-4 Years	229	42.49
5 years or more	195	36.18
Missing	7	1.3
Q5. Level of E-learning Knowledge		
Moderate	57	10.58
Good	183	33.95
Very good	224	41.56
Nothing	74	13.73
Missing	1	0.19
Q6. Extent of Willingness to Use M-learning Applications		
High	252	46.75
Medium	53	9.8
Low	233	43.22
Missing	1	0.19
Q7. Frequency of Online Service Usage for Learning		
1 time per week	42	7.79
1-5 times per day	199	36.92
5-10 times per day	139	25.79
More than 10	40	7.42
1 time per week	117	21.71
Missing	2	0.37
Q8. Internet Plan		
Mobile postpaid SIM with Internet service	279	51.76
Prepaid SIM card with Internet service	12	2.23
Data SIM card	83	15.4
DSL	165	30.61
Missing	0	0
Q9. Type of Internet Service Providers (ISPs)		
Wi-Fi	73	13.54
3G	322	59.74
4G	136	25.23
Missing	8	1.48
Q10. Kind of Smartphone Used (Multiple Answers Possible)		
Smartphone	373	69.2
Tablet/ iPad	73	13.54
Ultra laptop	84	15.58
PDA/palmtop	9	1.67
Missing	0	0
Q11. Preferred Device for Use in M-Learning (Multiple Answers Possible)		
Smartphone	501	92.95
Tablet/ iPad	365	67.72
Ultra laptop	428	79.41
PDA/palmtop	227	42.12
Missing	3	0.56

Appendix B: The Hypotheses of Moderators

A. The Hypotheses of Gender Moderator

H1. Increased performance expectancy will have a positive effect on the behavioural intention to use M-learning for female more than for male users of mobile devices.
H2. Reduced effort expectancy will have a positive effect on the behavioural intention to use M-learning for female more than for male mobile device users.
H3. The lecturer's influence has a positive or negative influence depending on whether they support and understand M-learning for female more than for male users of mobile devices.
H4. Increased personal innovativeness has a positive effect on the behavioural intention to use M-learning for female more than for male users of mobile devices.
H5. Increased 'mobile application system quality' has a positive influence on behavioural intention to use M-learning more positively for female than for male users of mobile devices.
H6. Increased 'mobile application service quality' has a positive influence on behavioural intention to use M-learning more positively for female than for male users of mobile devices.
H7. Increased 'mobile application interface quality' has a positive influence on behavioural intention to use M-learning more positively for female than for male users of mobile devices.

B. The Hypotheses of Experience Moderator

H8. Increased performance expectancy will have a positive effect on the behavioural intention to use M-learning for more experienced users of mobile devices than for less experienced users.
H9. Reduced effort expectancy will have a positive effect on the behavioural intention to use M-learning for more experienced users of mobile devices than for less experienced users.
H10. The lecturer's influence has a positive or negative influence depending on whether they support and understand M-learning for more experienced users of mobile devices than for less experienced users.
H11. Increased personal innovativeness has a positive effect on the behavioural intention to use M-learning more positively for more experienced users of mobile devices than for less experienced users.
H12. Increased 'mobile application system quality' has a positive influence on behavioural intention to use M-learning for more experienced users of mobile devices than for less experienced users.
H13. Increased 'mobile application service quality' has a positive influence on behavioural intention to use M-learning for more experienced users of mobile devices than for less experienced users.
H14. Increased 'mobile application interface quality' has a positive influence on behavioural intention to use M-learning for more experienced users of mobile devices than for less experienced users.

C. The Hypotheses of Voluntariness of Use Moderator

H15. Increased performance expectancy will have a positive effect on the behavioural intention to use M-learning more positively in voluntary users of mobile devices than it does in less voluntary users.
H16. Reduced effort expectancy will have a positive effect on the behavioural intention to use M-learning more positively in voluntary users of mobile devices than in less voluntary users.
H17. The lecturer's influence has a positive or negative influence depending on whether they support and understand M-learning more positively in voluntary users of mobile devices than in less voluntary users.
H18. Increased personal innovativeness has a positive effect on the behavioural intention to use M-learning more positively in voluntary users of mobile devices than in less voluntary users.
H19. Increased 'mobile application system quality' has a positive influence on behavioural intention to use M-learning more positively in voluntary users of mobile devices than in less voluntary users.
H20. Increased 'mobile application service quality' has a positive influence on behavioural intention to use M-learning more positively in voluntary users of mobile devices than in less voluntary users.
H21. Increased 'mobile application interface quality' has a positive influence on behavioural intention to use M-learning more positively in voluntary users of mobile devices than in less voluntary users.

Online Discussion Support System with Facilitation Function

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***Abstract*—In this paper, we present a discussion board system (DBS) with a facilitator function that we developed for the purpose of facilitating discussions that require decision-making that incorporates diverse values and opinions. Its function is to constantly extract nouns from the utterances of discussion participants and display them on the DBS on each participant's personal computer. Items to be decided in the discussion are displayed together with a frame (called a "box"), and each participant puts the displayed keywords in the box according to their own opinions and intentions. No other participant can see what the individual is doing. The color of any keyword that all participants put in the same box changes to green. Furthermore, comments are automatically presented based on the time when each participant last spoke and the time when the keyword was moved. This is intended to encourage participants who appear to be less involved to join the discussion. Experiments with the DBS suggested that it might be possible to capture the will of participants who disagree but do not speak. However, it was also deemed necessary to post comments that encourage participants to express their intentions independently, and to have a mechanism that can link the motivated manifestation of intentions to appropriate actions.**

***Keywords*—Discussion board system; decision-making; facilitation function; diverse values and opinions**

I. Introduction

In recent years, the realization of "diversity management" has become an issue for Japanese companies. The diverse perspectives shared by employees of different genders, nationalities, and backgrounds are thought to enhance corporate competitiveness. However, discussions that touch upon diverse values are easily confused, and participants in the discussions can easily lose sight of their goals and the current situation. Participants may forget what they have and have not yet discussed, or may not be able to reach a conclusion in time due to conversation loops, derailments, and incorrect time allocation. Furthermore, in situations where the hierarchical relationships [1] among individuals is clear, such as meetings within a company, the "peer pressure" [2] [3] that must be synchronized with the remarks of superiors hinders participation. This is also a factor that causes participants to hesitate to express various perspectives. The existence of a facilitator [3] is thought to have a certain effect on reducing the peer pressure among participants and appropriately advancing discussions based on various viewpoints. Mori [3] organizes the roles of facilitators into four tasks. The first is "designing the process." The facilitator clearly sets the goals of the discussion [4] based on the objectives and deliverables and logically and psychologically designs the optimal process toward the goals. The second is "controlling the process." The facilitator controls the process of discussion and prevents emotional conflicts from interfering with the discussion. While maintaining neutrality, the facilitator encourages other participants to speak so that a small number of hardline opinions and peer pressure do not lead to a conclusion. The facilitator assumes a referee position for the participants and provides a psychological safety zone for them by approving and encouraging the expression of different opinions as a necessary act. The third is to "organize and inspire discussions." The facilitator inspires participation in the discussion by asking the participants questions, summarizing and paraphrasing the opinions they present, and organizing the story so that the overall understanding is deepened. The fourth is to "form an agreement." The facilitator elicits opinions from all participants as much as possible and gives a sense of conviction that the discussion was properly and adequately conducted. Identifying the right time, the facilitator encourages participants to reach conclusions and encourage consensus building.

Despite their benefits, competent facilitators are not always present in discussions and cannot play these roles. Therefore, based on the role of these facilitators, we aimed to develop an artificial intelligence (AI) facilitator capable of autonomously facilitating discussions. In this paper, as the first step toward the AI facilitator, we developed a discussion board system (DBS) that realizes some of the facilitator's functions [5][6]. We verify whether the support of the DBS system is effective in reducing peer pressure and providing a psychological safety zone for group discussions. This study does not cover discussions aimed at generating many ideas, such as brainstorming sessions. Similarly, it excludes guided discussions where it is best for a highly specialized person to take a leadership role and decide everything. What we envision is a discussion aimed at forming a collective consensus on a given set of issues and drawing conclusions after considering various opinions.

Related research will be described in the next section. Section III gives an overview of the DBS. Section IV describes the system design based on the facilitator function [3]. In Section V, we outline our experiment with the discussion using DBS ver. 1.0, which implements facilitator Functions 1 and 2. We analyze the differences between the conclusions that the participants perceive as "agreed" and the opinions left on each participant's DBS [5]. In Section VI, we outline our experiment with discussions using DBS ver. 2.0, which implements facilitator Functions 1–4. Analyses were conducted concerning whether the comments displayed by the DBS were useful for facilitating discussions. Furthermore, by considering the intentions of the participants in the discussion from the viewpoint of peer pressure, we consider the role required for AI facilitators in the future. The paper is summarized in Section VII.

II. Related Research

To date, many discussion support systems have shared their screens among all participants. The MERMAID provides a way for people remote from one another to share information in multimedia forms such as video images, voice, text, graphics, still images, and hand-drawn figures [7]. However, to maintain the consistency of the displayed contents among the participants, one must acquire the right to operate the shared screen. In recent years, it has become possible for multiple people to share a document, for example "Google docs," retrieve and quote discussions from previous meetings [8], evaluate participants' contributions to discussions and visualize these views to the participants [9], and indicate participants' degree of self-confidence using a six-point scale in order to generate clues regarding the possibilities for compromise [10]. In the system proposed in this paper, to secure a psychological safety zone, the space for displaying the participants' opinions is not disclosed to other participants during the discussion.

There are some existing systems for new idea-generation support. Gungen [11] was developed to perform the distributed KJ method. Combinator [12] supports a designer's new idea creation by combining familiar ideas. Nishimoto [13] developed a system that structurally visualizes keywords automatically extracted from the comments of each participant during a discussion based on a word's appearance rate and reproduction efficiency. Idea expander [14] and SWISS [15] are idea-generation support systems that present images searched for based on the participants' text chats [14] or utterances [15]. In contrast, this paper focuses on discussions aimed at forming group consensus on tasks and drawing conclusions.

In the systems for group decision-making meetings, INGA [16] is a system that automatically searches for and presents electronic data from meeting materials that are highly relevant to discussions based on keywords obtained from voice input. Ohira [17] aimed to evaluate participants' ability to discuss and improve motivation through a form of discussion called "gamification discussion." Shimizu [18] presented a system in which participants can vote on ideas during a discussion. Discussion Media [19] is a system in which each participant can arbitrarily input their stance regarding the presentation and any arguments with other participants using a button device. The system proposed in this paper also has a function for categorizing keywords into boxes, but these are not published to other participants during the discussion.

COLLAGREE [20] is an open web-based forum system that has facilitator support functions and was deployed during an internet-based town meeting in Nagoya, Japan as a city project led by its mayor. D-Agree [21] analyzes the words written on a bulletin board and automatically facilitates the discussion. The system proposed in this paper is intended for discussions among small face-to-face groups aimed at decision-making. The system also has a facilitation function that presents comments based on the time while each participant is silent and/or a history of moving words in a display created by the participant.

III. Discussion Board System

We developed DBS ver. 1.0 [5] (see Fig. 1) and ver. 2.0 (see Fig. 2) to promote good discussions. A "good discussion" in this study is defined as below:

- In the shortest time, draw conclusions related to all items that need to be considered.
- The consensus of more attendees is a better decision than one with a lower level of consensus.

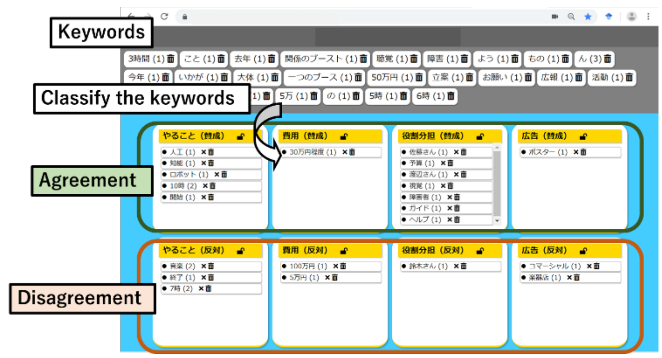

Fig. 1. DBS ver. 1.0.

Fig. 2. DBS ver. 2.0.

All attendees participate in the discussion. Even if they make no remarks, they will think of possible solutions to the problem and will ultimately be called upon to express their willingness / agreement with the decisions made.

A. Overview

The DBS displays the "boxes" of the categories to be decided in the discussion on each participant's screen. For example, in the case of the theme of "a gift," the terms "flowers," "fruits," "handkerchiefs," "accessories," etc. are displayed as category boxes on the DBS display.

The DBS uses speech recognition to extract nouns (hereinafter referred to as "keywords") from discussions and display them. Each participant can express their opinion concerning whether or not words are appropriate for the category by putting the keywords in the box using the “drag and drop” operation according to their opinion and intention, because each participant's screen is intentionally made invisible to other participants. For example, keywords such as apples and grapes are lined up on the display. If one participant puts “apples” in the “fruit” box, he is indicating the decision “if the gift is a fruit, apples are good.”

The DBS also presents boosting comments on the screen and encourages participants who have not spoken or manipulated the screen for a certain period of time to participate in the discussion with comments.

After the discussion is over, the number of keywords in the box is totaled. It is also possible to share the results among participants without revealing information about who moved which keyword to the box and when.

If all participants put the same keyword in one category box, the DBS will change the color of that word to green. Participants then know that other participants entered the same keyword in the category box.

The following sections detail the four functions of the facilitator, as realized by the DBS.

B. Function 1: Designing the Process

The DBS clarifies items to be discussed (goals), what has already been discussed, and what has not yet been discussed (current position). This feature helps participants reach the necessary and sufficient conclusions in time.

- Set a box on the terminal screen for each item to be decided (implemented in DBS ver. 1.0, 2.0).
- Show how many minutes are left to reach a conclusion (implemented in DBS ver. 2.0).
- Show the status of the box by commenting to all participants (implemented in DBS ver. 2.0).

Fig. 3 shows an algorithm for displaying comments (A) to (C). It is executed at regular intervals (every 8 minutes in Experiment 2) and displayed to all participants at the same time.

(A) It seems that “x (item name of the corresponding box)” is not filled yet.

(B) “x” seems to vary.

(C) It seems that “x” is just around the corner.

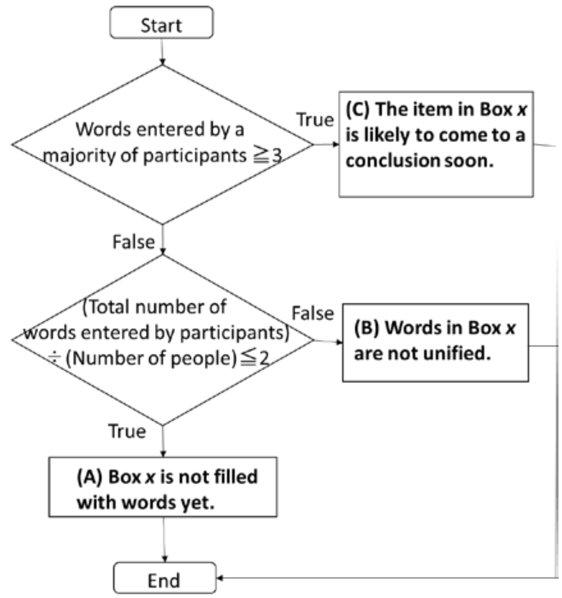

Fig. 3. An Algorithm for Displaying Comments A-C.

C. Function 2: Controlling the Process

The DBS provides a psychological safety zone to control the process of discussion and prevent emotional conflicts from interfering with it. Each participant moves the keywords to the box according to their own opinion and intention, without being seen by others. It is hoped that the true intentions of each participant will therefore be expressed. After the discussion of each item is concluded, participants press the “lock” button to indicate the discussion’s end. After the discussion is over, the system can aggregate the keywords in the boxes and share them among the participants. At that time, it is not clear who moved each keyword into the box. Therefore, the box area is a “semi-personal space” that can be shared by all participants while they easily express their personal opinions.

D. Function 3: Organize and Inspire Discussion

The DBS will display comments to encourage participants who have stopped speaking or moving keywords for a while to stimulate discussion. This function was implemented in DBS ver. 2.0. Fig. 4 shows an algorithm that is executed at regular intervals (every 8 minutes in Experiment 2) among the comments displayed to the relevant participants.

(D) (If there is only one participant who puts a keyword different from the others in the box) You put “keyword y” in “box x.” Would you like to give us your opinion on “y”?

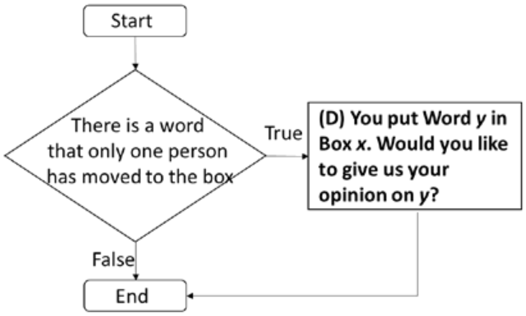

Fig. 4. An Algorithm for Displaying Comments D.

Fig. 5 shows an algorithm that is always running while the system is running and is presented to the relevant participants.

(E) You don't seem to have spoken for a while. Would you like to give us an opinion?

(F) You don't seem to have been operating for a while. Could you give me more ideas?

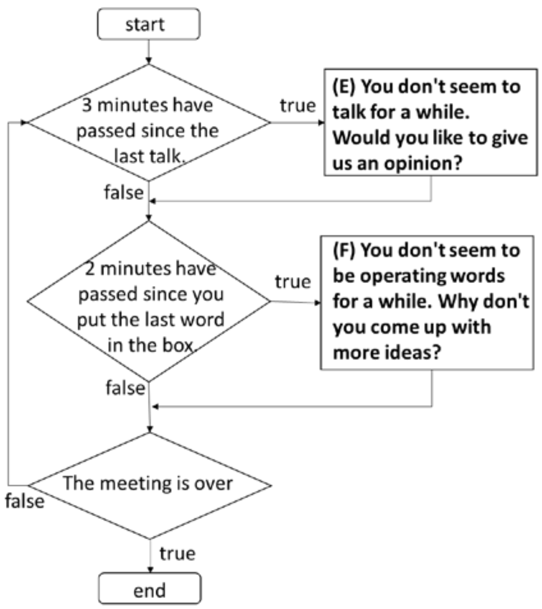

Fig. 5. An Algorithm for Displaying Comments E and F.

E. Function 4: Form an Agreement

When all participants enter the same keyword in the same box, the keyword changes to green (call this function a “deliverable display”) (implemented in DBS ver. 2.0). By turning green, participants know that all participants are likely to agree, and it is an opportunity to settle the discussion.

The “parking area” is a place to temporarily store keywords for which it is difficult to decide whether or not to put into a box (implemented in DBS ver. 2.0). The words in the parking area are disclosed to other participants. This function avoids the DBS treating words with the same intention as different words. For example, “Venice” and “Venetia” have exactly the same meaning, but they are recognized as different words in the DBS. However, if “Venice” is in the parking area, most of the participants will move “Venice,” not “Venetia,” into the box, when they agree with this word. This function is also useful for the deliverable display function.

F. Extracting and Displaying Keywords

Each participant’s voice is recognized by each personal computer, and the extracted keywords of all participants are displayed on all terminals at almost the same time [5][6]. As shown in Fig. 6, utterances are always recognized by the speech recognition capability of the “Web Speech API.” The recognized characters are parsed using the Japanese morphological analysis engine “kuromoji.js” or the named entity extraction API (selectable). “Keywords” are extracted from the word group after the parsing is completed. Suffixes and particles to be adnominal are grouped as the same keyword. Keywords are sent to the server and registered.

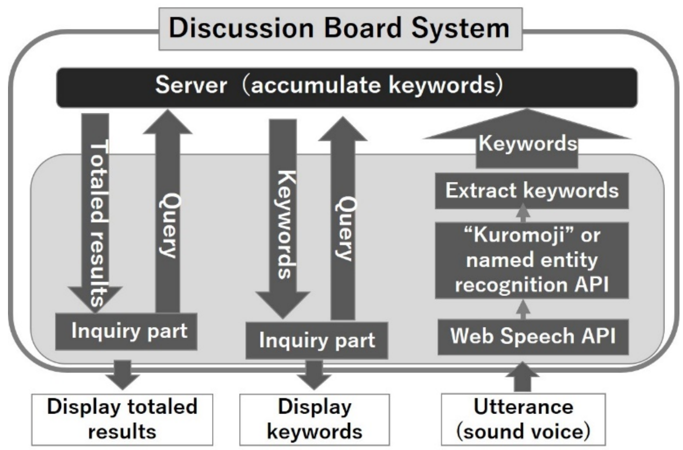

Fig. 6. System Flow.

At the same time that the voice recognition starts, the application inquires at regular intervals whether a new keyword is registered on the server. Keywords extracted from the utterances of all participants are targeted. If there is a new keyword, it will be acquired and displayed on the screen. The time of the inquiry server is recorded, and then only the keywords registered after the recorded time are acquired and the last inquiry time is updated. The inquiry interval can easily be changed by setting the DBS, and four types, of 0.5/1/2/3 seconds, are prepared, where the initial state is 1 second. In other words, the maximum set inquiry interval is delayed from the time the keyword is registered until the screen is displayed.

IV. Experiment 1

A. Purpose

DBS ver. 1.0 (Fig. 1) was used for the discussion, and the following two points were considered. (1) The effect of the box and (2) the usefulness of a semi-personal space. Regarding (2), we aimed to verify our findings based on the differences between individuals’ and overall decision-making, as estimated from the keywords left in the box.

B. Method

The participants in the experiment were four first-year male graduate students (participants A–D). Each participant was given a laptop computer with the DBS.

Of the four participants, two entered separate soundproofed rooms, while the other two sat in the opposite corners of a room approximately 50 square meters in area. Their discussion was held online using the Internet calling system Skype. No images were transmitted, only each participant's voice.

The agenda set for the four participants was "Think about how to entertain children and their parents at a fun kindergarten event."

The terms of the discussion were summarized on a piece of paper and passed to the participants: The performers were the four participants in this experiment / Days before the fun event / Performance time / Location / Room situation (fictitious photo with mini stage and speakers) / Kindergarten age / Gender / Number of children and parents / What to expect from the kindergarten / Background of the party (PR for becoming a kindergarten that you want to attend) / No budget.

The items to be decided during the discussion were specified by the experimenter. These were: 1. What to do, 2. Preparations, 3. Role sharing, and 4. Cost. Two types of boxes were provided for each item, "agree" and "disagree." For example, for the item "cost," if the participant agreed with "about 300,000 yen," he moved the keyword "300,000 yen" to the box marked "cost-agree." If not, it is moved to the box "cost-disagree." Keywords can also be moved to another box or deleted. A total of eight boxes were prepared. Prior to the experiment, the experimenter registered eight boxes in each computer's system. Participants were instructed to decide on these four items within a specific time.

It was requested that the movement of keywords to the box should be decided by the participants' own intentions and opinions, rather than taking direction from the group. We instructed all participants to decide these four items (agreement) within 40 minutes. The screen recording software "Filmora Scrn" was used to record the screens of each participant, in addition to their faces and utterances. However, due to a malfunction of the experimental equipment, it was not possible to capture the video for Participant C's screen.

C. Questionnaire Survey

After the experiment, the four participants answered Questionnaire 1 while seated at the same table. At the time of the experiment, the "item box" element was called a "category."

1) Questionnaire 1

Question 1-1: What was the conclusion of the discussion (concluded / not reached)? Please write the final conclusions of your perceived discussion by category (what to do / preparation / separation / costs). Do not consult with the other participants, and answer using your own words. If there are any categories for which you have not yet reached the end of the discussion, please write down the conclusions that you think are the most likely at this time. If there was not one conclusion, please describe all conclusions reached.

Question 1-2: What did you think and judge when moving keywords to the categories? Fill in as much detail as possible about the criteria for sorting and what you were thinking when moving the words.

Question 1-3: How did the discussion proceed?

- Was the discussion lively?
- Were participants' opinions easy to agree with?
- Do you feel that you reached the conclusion smoothly?

Next, the four participants responded to Questionnaire 2 while looking at the results of the totals for all eight items and their responses to Questionnaire 1.

2) Questionnaire 2

Please answer the following questions about Questionnaire 1, which you completed earlier, while looking at the display showing all of the results from all participants.

Question 2-1: What was the biggest difference between the final conclusion you reported in Questionnaire 1 and the actual results from all participants?

Question 2-2: Remember the flow of the discussion. Were there any times where your intentions and opinions were different from the opinion and story flow of the entire group? What did you think about that?

Question 2-3: Look at the tally results on the display. Are there any of your conclusions in Question 1 from Questionnaire 1 that you think should be corrected? If so, what are they?

D. Results

1) Participants' commenting behaviors: The following tends were observed from the analysis of utterances. The basic form of the discussion was that multiple opinions were presented in response to the questioning remarks (for example, "Is there anything other than the play?" "What are the preparations?"), and the most-supported remarks were expanded to the next discussion. When there were concerns or points to be noted regarding the remarks, the behavior was seen in which the topic was interrupted, rather than expressing dissenting opinions. Participants sometimes suddenly made remarks that were not linked to those immediately before. For example, immediately after "cleaning up time is about 5 minutes," They switched to the next discussion with "then, preparations." In the latter half of the discussion, participants began to speak with an emphasis on nouns.

2) Keywords left in the box: Table I shows the keywords that finally remained in the box and the aggregated results. There were almost no differences in the number of keywords between items other than "cost" and among the participants. However, all four participants put only five keywords in the same box, four of which were in "role division." In "what to do," two people put "magic" and another two put "magic tricks." These two keywords are considered synonymous, so it can be said that there was a total of six common keywords. Participants B and C left the "curtain" in the "preparation (agreement)," while A put it in the "preparation (opposite)." Analyzing the utterances, Participants A, B, and C recognized that they would use the kindergarten curtains. However, B and C put the keyword in “agree,” in the sense of “preparing the curtain,” while A put it in “opposite,” in the sense that “the curtain is at the kindergarten, so no preparation is necessary.”

TABLE I. KEYWORDS LEFT IN EACH BOX

category	participant	remaining keywords	totalization
what to do (agree)	A	Momotaro, Oni(devil), workshop, magic (in English), juggling, Talk (free conversation), lecture, background music	one using cards(3), magic (in English)(2), magic (in Japanese)(2), juggling(3),participation(2), workshop (2), simplification, Momotaro, Oni, lecture, background music, Talk, participation, communication
	B	one using cards, magic, simplification	
	C	one using cards, magic (in English), juggling, magic (in Japanese)	
	D	participation, workshop, one using cards, juggling, communication	
what to do (disagree)	A	arrangement of effects, projection mapping	Momotaro(2) arrangement of effects, projection mapping(2)
	B	Momotaro, projekution mapping	
	C	Momotaro	
	D	--	
preparation (agree)	A	banana, cards, costume for a behind-the-scenes supporter	handkerchief(2), banana(4), cards(3), curtains(2), costume for behind-the-scenes supporter(2), cloth of a dog, low-cost, beanbags, bowling pins
	B	handkerchief, low-cost, banana, cards, curtains, beanbags	
	C	handkerchief, banana, cloth of a dog, cards, curtains	
	D	banana, teacher, cards, beanbags,bowling pins, costume for a behind-the-scenes supporter	
preparation (disagree)	A	curtains, spotlight, building clocks, projector	spotlight(2), 10 pieces, wall, hole, curtains, building clocks, projector
	B	10 pieces, wall, hole	
	C	--	
	D	spotlight	
role sharing (agree)	A	assistant, a behind-the-scenes supporter, moderator, magician	assistant(4), a behind-the-scenes(4), moderator(4), magician(4), background music(2), Neta, juggling, teacher
	B	Neta (a joke material), assistant, a behind-the-scenes supporter, moderator, juggling, teacher, background music, magician	
	C	assistant, a behind-the-scenes supporter, moderator, magician	
	D	assistant, a behind-the-scenes supporter, moderator,background music, magician	
costs (agree)	A	--	4000 yen (3)
	B	4000 yen	
	C	4000 yen	
	D	4000 yen	
costs (disagree)	A	4580 yen	4580 yen (2) price of a dog
	B	4580 yen	
	C	price of a dog	
	D	--	

TABLE II. RESULTS OF QUESTION 1-1.

Category	Participant	Conclusion	Final conclusions recognized by individuals	Difference in number from words left in the box
What to do	A	yes	magic show	Seven words decreased
	B	yes	magic	Two words decreased
	C	yes	magic	Three words decreased
	D	yes	magic, juggling	Four words decreased
Preparation	A	yes	banana, cloth, cards, ling, beanbags	One word decreased, three words increased
	B	yes	handkerchief, cards, ball for juggling, cloth, banana	Three words decreased, two words increased
	C	yes	handkerchief, banana, cards, curtain	One word decreased
	D	yes	banana, beanbags, cards, cloth, costume for a behind-the-scenes supporter	Two words decreased, one word increased
Separation	A	yes	magician, moderator, assistant, a behind-the-scenes supporter	No change
	B	yes	magician, moderator, assistant, a behind-the-scenes supporter	Four words decreased
	C	yes	magician, moderator, assistant, a behind-the-scenes supporter	No change
	D	yes	magician, moderator, assistant, a behind-the-scenes supporter	One word decreased
Costs	A	yes	4000 yen or less	"4000 yen" remained
	B	yes	about 4000 yen	"4000 yen" remained
	C	yes	4000 yen	No change
	D	yes	4000 yen?	"4000 yen" remained

3) Relationships between utterances and keyword movement: There was one example in which the intention expressed in the participant's utterance and the intention expressed in the movement of his keyword were different. Fragment 1 shows the example.

Fragment 1 (English translation):
01B: What Participant C said a little while ago. I think it is one of the good ideas.
02D: Is it an idea what someone eats bananas?
Participant D put “banana” in the “preparation (agreement)” box.
03B: The banana disappeared because one of us ate the banana, didn’t it?
04C: Oh.
05D: So, it was a good hook.
06B: It was a good hook.
07C: It was a good hook.
Participant A put “banana” in the “preparation (agreement)” box.

They are talking about eating bananas as a comical means of realizing magic tricks where objects disappear. Member B did not put the “banana” in the box after all, even though he made a favorable and agreeing statement about magic and using bananas.

4) Questionnaire results: Table II shows the results of Question 1-1, compared to the keywords written there with the keywords in the “Agree” box (Table I), and it shows the number written in only one of them. All participants judged that all items were “concluded.” The final conclusions each participant wrote in the questionnaire were roughly the same for all four; however, especially for the items of “what to do” and “preparation,” there was a large difference between the keywords left by each participant in the DBS box and the questionnaire responses.

There were slight differences in the answers to the “cost” questionnaire, such as “4000 yen,” “4000 yen or less,” and “about 4000 yen,” and it is possible to read the difference in the recognition of the participants. Regarding Question 1-2, All participants but C sorted the keywords into boxes at their own discretion. The average values of the answers to the three questions (four levels of answers) in Questions 1–3 were 3.25, 3.25, and 3.5, respectively. Participants felt that the discussions were lively, the opinions tended to be the same, and the conclusions were reached smoothly. Question 2-1 showed that the results perceived by the participants themselves and the aggregated results including others were slightly different, in terms of preparation and the division of roles. In Question 2-2, Participant B wrote, “How to erase (object) with magic tricks, I answered BOX, and the others were cloth (answered)," while D said, "The item of division of roles, who played that role." There was a slight discrepancy among the participants in their perceptions of the debate about what to do. It turned out that there was a discrepancy in the details. In Question 2-3, all participants looked at the keywords left by other members in the box and indicated their willingness to add or modify keywords for all four items.

E. Discussion

The DBS has the ability to display boxes for items to decide on. As a result, participants may be motivated to fill an empty box. Therefore, the next discussion (topics about empty boxes) may suddenly begin, regardless of what was being talked about immediately before. This is considered to have contributed to the fact that all items could be decided within the specified time. Later in the discussion, participants tended to speak around nouns to make them more visible in the DBS. This had the effect of preventing ambiguity about each speaker's intent. However, noun-centered remarks also had the effect of eliminating complex content and nuances, as shown by the example of the subtle variations seen in the "cost" questionnaire response.

The conclusions that each participant recognized after the discussion ended were almost the same among the participants. In other words, it can be said that the consensus was formed by the discussion, and the participants correctly recognized this. However, there were differences in the keywords that remained in each participant's box. In addition, there was one case (the example of the "banana") in which participants did not move keywords despite returning a positive response.

Some situations were observed during the discussion. When someone expressed concern about an idea, even if it was just a confirmation act, the other participants might recognize that the idea was denied and stop considering it and move on to another topic. As the banana example shows, participants always had to react positively, so that they would not take each idea out of consideration. Participants did not disagree with the other participants, even though the keywords left in the box differed from the overall conclusion. Based on these results, during the discussion process, each participant was able to freely express their personal opinions and intentions on the individual display (semi-personal space) of the DBS without fear of denying the ideas of others.

Also, in this experiment, the "opposite" box was almost non-functional. This is because it was sufficient for participants not to move the keyword to the "agreement box" if there was any objection.

V. Experiment 2

A. Purpose

We conducted a second experiment using DBS ver. 2.0 to show changes in participants' behaviors by displaying comments during discussions, and to try to estimate participants' intentions based on their movement of keywords.

B. Method

Participants were three males in the second year of a master's program (Participants E–G) and one male in the fourth year of the undergraduate program (Participant H). They received an explanation of the experiment, signed a consent form, and then participated. Each participant was given a desktop personal computer displaying DBS ver. 2.0.

The experiment was conducted in the same room as the experiment outlined in Section 5. Participants E and H each entered a separate soundproof room, and F and G sat diagonally from one another across a large room. The four made voice-only calls using the Internet calling system Microsoft Teams.

The subject of the discussion was the same as in Experiment 1, but a fictitious reward was added to further motivate the participants. The content of the reward was "If the kindergarten teacher and parents voted the plan for the first place, the university will cover the cost of the gift up to 10,000 yen." Participants acknowledged that the setting was fictitious and started the discussion. The items to be decided in the discussion were the same as the experiments in Section V.

C. Questionnaire Survey

After the discussion, we asked each participant to answer a questionnaire about the comments displayed on the DBS during the discussion. These comments were displayed on a separate display from the DBS, for the purpose of encouraging participants to take specific actions. At the beginning of the questionnaire, a list of comments (Comments A– F), as shown in Section IV, was provided. Not all comments were displayed to all participants, because the timing and content of comments displayed varied from participant to participant. Therefore, some participants had not seen some of the comments in the survey on the DBS.

1) Question 1: Do you think there were any comments that changed the flow of the discussion? If there were, write the symbol of the comment (A) to (F) and what kind of change it made. It doesn't matter as long as you remember.

2) Question 2: Please rate each comment (A– F). Did the comments make it easier for you to speak? We asked them to circle the applicable numbers from "Comments did not trigger speaking (1)" to "Comments triggered speaking (5)." Also, if they had any impressions of the comments, they were asked to write them in detail. If they had a comment that was not displayed, they were asked not to reply.

D. Results

1) Keywords left in the DBS box: In the end, a total of 73 keywords remained in the boxes of the four participants. There was almost no difference in the number of keywords among the participants. All participants had the highest number of keywords in "preparation."

Six of the remaining keywords were converted to green during the discussion. (If all participants put the same keyword in the same item box, it turned green.) There was 1 for "what to do," 3 for "preparation," and 2 for "role division." The keyword "game" turned green once, but returned to colorless at the end because Participant E removed it from his box. Regarding the cost, both "10,000 yen" (3 people) and "free" (2 people) remained, so we can see that these were not decided.

2) Questionnaire results: In Question 1, Participants F, G, and H answered that "Comment (A) changed the flow of discussion." In Question 2, as well, comment (A) led the same three people as in Question 1 to be "triggered to speak." On the other hand, G replied to comment (B), "I couldn't think of how to make a statement."

Participant F had the impression that "I personally felt that it was organized," in response to the comment (C). Participant H replied that even if comments (D), (E), and (F) were displayed, they did not lead him to speak.

3) Behavior seen after displaying comments: Participant E let go of the mouse and spoke, but when Comment (F) was displayed, he put the keyword "cardboard" in the "what to do" box. This keyword was not directly related to what was being said at the time. At the same time, he deleted the keyword "drama" from the "what to do" box. Participant G also let go of the mouse and spoke, but when comment (F) was displayed, he seemed to touch the keywords in the parking area one by one with the cursor. However, he eventually started the next statement without moving any keywords. Participant H was laughing while listening to the other participants but not speaking, and he did not move the cursor at all. Once comment (F) appeared, he started moving the cursor and put the keyword "cardboard" in the "preparation" box.

4) Participants' opinions estimated from the movement of keywords: In this section, we extracted the utterances of each participant and the movement of keywords on the DBS to try to estimate the change in the participants' thoughts based on these actions. The subject was the keywords "game" and "VR" in the "what to do" box, and the changes in the intentions of Participants E and F for them.

The underlined part shows their utterance excerpts and indicates the display and movement of the keyword. Fragment 2 shows the reactions of other participants to Participant E's proposal "game" and "VR (virtual reality)."

Fragment 2 (English translation):

4'47"

08E: Young children seem to like games and VR.
"Game" is displayed in the text area. F puts the keyword "game" in the parking area.
09E: You see, the teacher's son was very excited about VR. What do you think?
<u>"VR" is displayed in the text area. G puts "VR" in "what to do."</u>
10F: Oh, that might be fine. It doesn't cost much to prepare.
E puts "game" in the "what to do" box.

Participant E only put "game" in the box, but it can be inferred from his utterance that the participants were speaking in a state where the concepts of VR and game were not so distinguished. It is probable that they tried to proceed as with the ambiguous idea of whether it was VR or a game. Participant F made a positive statement, "that might be fine," and moved only the keyword "game" into the parking area. The fact that he did not put the keyword in the box as a decision suggests that the proposal was still considered a candidate for him at that time.

Fragment 3 is an excerpt from the conversation after Participant E proposed attaching cardboard to a smartphone (VR goggles).

Fragment 3 (English translation):

7'19"

11F: I think the game might be better.

12E: Yeah.
13F: I think it's easy to imagine.
(10 seconds)
14E: There is no restriction that the event must be on stage. (5 seconds)
15G: There is only a designation to carry it out in the play room.
16E: How about bringing some candidates for the time being?
<u>H puts "game" in the "what to do" box.</u>
17E: 26 children.
18G: That's right
<u>G puts "game" in the "what to do" box. The word "game" in the "what to do" box turns green.</u>

Participant F momentarily hovered his cursor over "VR" in the parking area, but did not move it to the box or put the adjacent keyword "game" in the "what to do" box.

Participant F was concerned about the "VR" in the parking area, but put only the word "game" in the box, before immediately saying, "The game may be better." From this utterance, the following two points can be inferred. F thought that the "VR" plan and the "game" plan were different. At that time, the participants' conclusions tended toward "VR," but F thought that the conclusion of "games" was good.

Participants H and G also put the keyword "game" in the box, and the word "game" turned green. However, the thoughts of the other participants remained unclear, and the topic changed to a place for the show. Neither G nor H had given a concrete opinion on the idea of VR or the game. It is possible that F's remarks triggered them to just put the "game" in the box.

Fragment 4 is an excerpt of a conversation that begins with G's question about the content of the game.

Fragment 4 (English translation):

9'27"

19G: The rest of the tasks are what the game will be. What to do with the contents.
<u>E puts "VR" in the "what to do" box.</u>
14'50"
20G: How about fetching material from YouTube? Like a roller coaster.
<u>H puts "VR" in the "what to do" box.</u>

Immediately after G asked about the game, E put “VR” in the box. He may have wanted to push the VR plan in opposition to the game plan.

Fragment 5 is an excerpt of a conversation that begins with G's question about expensive preparations.

Fragment 5 (English translation):

24’22”

21G: I [can] borrow a 360-degree camera from my acquaintance's laboratory. Is there anything else (expensive)?
E removes “game” from “what to do.”
(Omission)
30’09”
22E: Like a VR aquarium…
23F: That's a good idea.
F puts “aquarium” in the parking area.
(Omission)
33’13”
24G: We may place an order outside.
25E: Order?
F puts “aquarium” in “preparation.”
26E: How about using Fablab?
F puts “VR” in “what to do.” The term “VR” in the “what to do” box turns green.

In response to G's remark, E deleted the “game” that had been converted to green.

In the first place, E considered games and VR to be separate ideas. It is also thought that he was convinced that the “game” plan and the “VR” plan, whose recognition was ambiguous among the participants, proceeded to VR following the remark about G’s “360-degree camera.”

After that, F put “VR” in “what to do” and the keyword “VR” was converted to green. F agreed with E’s “VR aquarium,” but did not remove “game” from the box at that time. It is thought that F recognized that the VR plan was being finalized and accepted it because G made a statement on the premise of the VR plan (the external order for a 360-degree camera).

E. Considerations

Regarding Function 1, “designing the process,” participants completed discussions on four items within the time limit, suggesting that the box is useful, as was the case of the experimental results in Section V.

Regarding Function 2, “controlling the process,” Participant F put a “game” in the box and then immediately said, “A game may be better.” It is thought that this encouraged the remarks of others.

By contrast, while Participants E and F tended not to hesitate to express their opinions to others, a conversation analysis suggested that G’s remarks determined the flow of discussion.

It cannot be denied that the reason why F could not push the “game” plan to the end was that the movements of G and E came as a result of sympathetic pressure. The movement history of keywords may be effective in guessing participants’ true intentions, and by using this, it is possible to promote discussions from multiple perspectives. In addition, the flow of the discussion may have changed if the concrete examination of the game content was advanced at the initial stage of the discussion. To broaden the effectiveness of the discussion, it was considered necessary to have a mechanism for prompting other non-independent participants to think and speak concretely about each proposal.

Regarding Function 3, “organize and inspire discussions,” participants answered in the questionnaire that comment (A) triggered them to review their utterances and keywords. When analyzing the behavior after the comment was displayed, there was a tendency to move the cursor and put the keyword in the box after comment (F), “It seems that you have not operated for a while,” is displayed (see Fig. 5). However, some participants tried to move the cursor to do something, but did not move the keyword. Based on this, it can be said that, although the comments aroused a motivation to take action, there was not always an appropriate action to match it. The DBS generates keywords based on utterances, so even if non-speaking participants have different opinions, there is no matching keyword.

Regarding Function 4, “form an agreement,” in Experiment 1, in Section V, the common keyword was biased toward the “role division” box. However, in Experiment 2, in this section, there was a common keyword that turned green in the three boxes other than “cost.” The deliverable display function that changes the color of the common keyword clearly indicates whether each item has been decided or left undecided, so it may have been effective for drawing conclusions. However, although E deleted the keyword “game,” which had converted to green, and G and H also put “game” in the box, there were few remarks suggesting a game plan. Based on this, we can say that, if there is no particular objection to the keyword, it may be put in the box according to the flow of discussion, or the keyword, once put in the box, may not necessarily be in favor, due to the flow of discussion. At the beginning of the experiment, participants were asked to “put keywords that match their intentions in the box,” but this instruction was not thorough enough, and it seems that the boxes were used, instead, as a record of the overall opinion. In order to realize Function 4, it may be necessary to strengthen the work of inputting the individual intentions of each participant into the DBS, instead of the overall opinion, and at the same time, to confirm the individuals’ conclusions.

VI. Discussion

We experimentally examined the functions required for a system that helps participants to form a consensus and draw conclusions after giving various opinions during an online discussion.

The deliverable display function that changes the color of the common keyword clearly indicates whether each item has been decided or left undecided, so it may have been effective for drawing conclusions. However, if we do not ensure that participants put only their personal conclusions in the box, the boxes can become just notes on the discussion.

We also discovered some concerns. It is possible that some participants will try to settle the discussion and invite other participants to move a keyword in order to turn it green. This action may promote peer pressure that is contrary to the purpose of the DBS. It can be said that the AI facilitator not only displays comments that encourage discussion, but also has a mechanism for protecting participants from peer pressure. To that end, there is a need for a mechanism that eliminates the above concerns, encourages silent participants to think independently, and links their aroused willingness to manifest their intentions to appropriate actions.

VII. Conclusion

This paper proposed a discussion board system (DBS) for a future AI facilitator. The following four facilitator functions have been realized: 1) Design the process, 2) Control the field, 3) Inspire discussions, and 4) Form consensus.

Experiments with the DBS suggested the following:

1) By displaying the items to be decided, the topic can be easily changed to the next agenda item, and a conclusion can be drawn within the allotted time.

2) If the discussion participants can express their opinions and intentions on a screen that cannot be seen by others, peer pressure can be avoided to some extent.

3) The comments displayed from the system prompts users' operations on the screen. The comments triggered them to review their utterances and keywords.

4) The deliverable display function that the keyword changes to green when all participants enter the same keyword in the same box provides an opportunity to settle the discussion.

In a future effort, we aim to create a system that encourages participants to express their intentions independently by solving problems and examining the content of the comments to be displayed, and to further reduce the influence of peer pressure in the discussion.

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Hybrid Spelling Correction and Query Expansion for Relevance Document Searching

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***Abstract*—A digital library is a type of information retrieval (IR) system. The existing IR methodologies generally have problems on keyword searching. Some of search engine has not been able to provide search results with partial matching and typographical error. Therefore, it is required to be able to provide search results that are relevant to keywords provided by the user. We proposed a model to solve the problem by combining the spell correction and query expansion. Searching is starting with indexing the title of the document by preprocessing the title of all incoming document data and then weighting the Term Frequency – Inverse Document Frequency (TF-IDF) against all terms of the whole document. Levenshtein Distance algorithm is used in the search process to correct typo-indicated keywords. Before calculating the relevance between the keywords and the documents using Cosine Similarity, the keywords are expanded using Query Expansion to increase number of documents retrieved. Calculation results using Cosine Similarity are then added to Query Expansion weight calculation to get final ranking result. Results show improvements over IR system compared with system without spell check and query expansion. The results of the study in the form of web-based application conducted testing for 50 times with number of data of 2,045. The system was able to correct typo-indicated keywords and search documents with average recall value of 95.91%, average precision value of 63.82% and average Non Interpolated Average Precision (NIAP) value of 86.29%.**

Keywords—Cosine similarity; information retrieval; Levenshtein distance; TF-IDF; typographical error; query expansion

I. Introduction

Digital library is one of information service providers in the forms of digital documents that can be accessed online. It is very helpful for students in searching information to complete assignments as well as searching supporting documents for research they are conducting. The large number of digital documents at digilib makes the scope of information search even greater so that information and the needs of relevant information are increasing [1]. Based on observation, some digilib has not been able to provide search results with partial matching and typo-indicated keywords (typing error).

In searching information, the model used and the choice of keywords can influence the level of document relevance towards user's keywords. One of them is VSM (Vector Space Model) where this model represents documents into the forms of vector space. VSM enables to determine relevant documents with keywords depending on the similarity measurement [2]. One of popular VSM measurement models is Cosine Similarity that calculates the cosine angle between two vectors. In addition, Cosine Similarity can be implemented on document matching and partial matching [3]. With the ever increasing size of the web, relevant information extraction on the Internet with a query formed by a few keywords has become a big challenge. Query Expansion (QE) plays a crucial role in improving searches on the Internet [4]. Query expansion plays a major role in reformulating a user's initial query to a one more pertinent to the user's intended meaning. It is to retrieve the most relevant expansion words for expanding the initial query of the user in order to enhance the outcomes of web search results. The reformulated query is then used to obtain more appropriate outcomes from a large amount of information on the web [5].

Spelling errors are words that spell-checker could not find in its lexicon [6]. Typo on keywords is one of reasons why the search result is not relevant since keywords entered are not in the database, so the search engine cannot find relevant documents with the typo-indicated keywords. Several research on search engine concluded that the keyword spelling errors by users are relatively high [7]. The causes for errors are usually related to writing ignorance, positions of keyboard buttons, and finger's movement [8]. Therefore, it needs spelling correction. Levenshtein Distance, also called edit-distance, is used to find word candidates suggested based on number of minimum characters that need to be substituted, inserted, or deleted to change words from string A to be string B [9]. Levenshtein Distance provides good results in solving problems of matching string data to provide text suggestion, for instance in handwriting recognition, search words and misspelled words, so the input effectiveness increases, misspelling can be avoided and auto-complete accelerates human computer interaction [10] [11].

Based on problem explanation, the researchers conducted research to improve the relevance of document search by using Query Expansion, Levenshtein Distance algorithm and Cosine Similarity calculation.

II. Literature Review

A. Text Preprocessing

Text Preprocessing is a process to bring unstructured data form into structured one as needed for further processing in text mining. In this research, text preprocessing is for the titles of research documents and query from users [12]. It uses several general processes such as:

1) Case folding: a process of changing letters in a document into upper-case or lower-case. In this research, lower-case is used.

2) Tokenizing: a process of breaking down string into some smaller units called term. Token can be in the forms of a word / number, sentence or paragraph. In this research, term from the tokenizing result is in the form of a word [13].

3) Filtering: a process of removing symbols from string. In this research, all symbols except for alphanumeric are removed.

4) Stopword removal: a process of removing unessential words in the description by checking words of description parsing result whether they are in the unessential word list (stoplist) or not for instances are conjunction “adalah”, “dan”, “dari”, “yang”, “di” and “ke” [14].

5) Stemming: a process of removing affixes including prefixes, infixes, and or suffixes on the word group to process.

This research adds one more process to change acronym into its original form in order that term table for TF-IDF weighting becomes more structured.

B. Synonym Table Formation

Every word included in the wordlist table is then processed to find its synonym as Query Expansion reference. The search of synonym uses scraping technique towards webpage of kamuslengkap.com. The results of synonym are then stored in the wordlist table as shown in Fig. 1.

C. Query Expansion

Query Expansion reformulates user’s original query to improve the effectiveness of information retrieval [15]. The use of query expansion in this research aims at increasing recall value by taking documents that have similar meaning or synonym with terms from query. The process of query expansion is done to term that has not experienced stemming [16]. Table I used for searching synonym of keywords is wordlist table containing word group from documents and the synonyms that have been found through prior scraping. For instance, if we need to search with keywords “Pencarian dokumen” (document search), each term will be expanded based on the synonym of each term in the wordlist table.

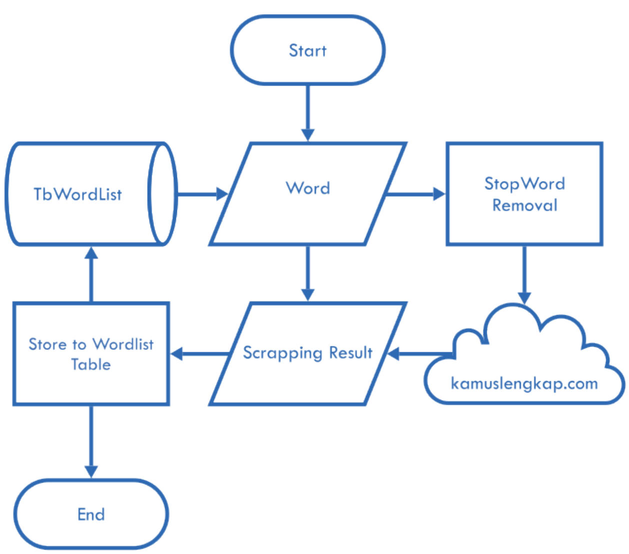

Fig. 1. Process of Synonym Table Formation.

TABLE I. SYNONYM OF KEYWORDS

Keyword	**Expansion**
Pencarian	*Penelusuran, Pelacakan*
Dokumen	*Arsip, Naskah*

Therefore, documents to search are not only those with terms “pencarian” and “dokumen” but also “penelusuran”, “pelacakan”, “arsip” and “naskah”.

D. Term Frequency- Inverse Document Frequency (TF-IDF)

TF-IDF is a process of weighting a term of a document towards the whole document. TF-IDF calculation is a technique that weighs relevance of term towards document by combining two concepts in weighting, namely the frequency of a term occurs in a document (term frequency) and inverse document frequency containing the term [17].

Term Frequency (TF) that frequently occurs in documents becomes more critical since it can indicate the topic of documents. There are some formulas used to calculate term frequency in documents, but in this research TF calculation uses binary TF that focuses on a term in documents. If it is found, it scores one (1) regardless of the occurrence frequency in documents. If it is not found, it scores zero (0). Inverse Document Frequency (IDF) is used to indicate discriminative power of term i. Generally, terms that occur in a variety of documents less indicates of a particular topic. Formula of inverse document frequency is defined as followings:

$$idf_i = log\left(\frac{n+1}{df_i+1}\right) + 1 \tag{1}$$

Where df_i is document frequency of term i or number of documents containing term i and n is the number of all documents.

Weight W_ij is the multiplication result of term frequency matrix and IDF value of each term that can be defined as followings:

$$W_{ij} = tf_{ij} \times idf_i \tag{2}$$

Where df_i is document frequency of term i or number of documents containing term i and n is the number of all documents.

TF-IDF weighting is done to terms previously collected in TermList table. Fig. 2 shows the flow [18][19].

E. Spell Checker

Spellcheck is a technique that identifies incorrect words or misspelled words then changes them into correct word combinations properly. There are two main methods used to develop spelling checker application, namely identification (error detection) and correction (error correction). Besides, spelling checker is divided into two types, namely non-word error spell checker and real-word spell checker. Non-word error spell checker manages misspelled words due to typing errors, while real-word error spell checker manages substitute words to replace errors in the sentence [20] [21].

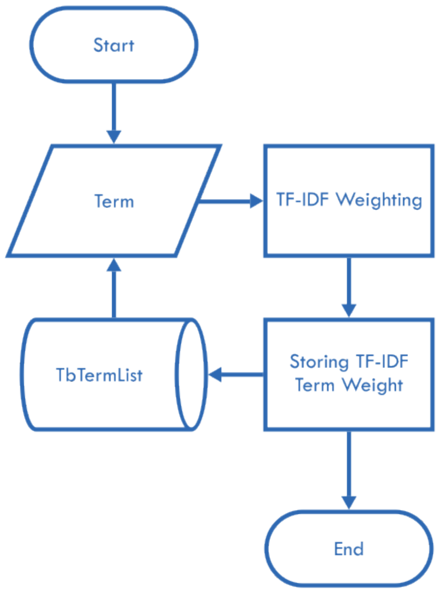

Fig. 2. Process of TF-IDF Weighting.

F. Levenshtein Distance

Levenshtein Distance is an algorithm that measures distance between two strings by calculating number of minimum operations needed to change one string to another. The operations are deletion, insertion, and substitution. Mathematically, Levenshtein Distance between two strings can be formulated as followings:

$$lev_{a,b}(i,j) = \begin{cases} max(i,j) \\ min\begin{cases} lev_{a,b}(i-1,j)+1 \\ lev_{a,b}(i,j-1)+1 \\ lev_{a,b}(i-1,j-1)+1_{a_i \neq b_j} \end{cases} \end{cases} \quad (3)$$

In this research, Levenshtein Distance algorithm is used to process user's query to find out whether query typed by users is indicated typo or not. The typo-indicated words are those that are not in the wordlist table [22]. This process calculates the distance of words in query with word groups in the wordlist table. The words chosen as the correction result from the typo-indicated query words are those with the closest distance based on Levenshtein Distance calculation.

G. Relevance Calculation with Cosine Similarity

In this stage, calculation of relevance using Cosine Similarity between query and document from TF-IDF weighting previously obtained is done. The results are in the forms of similarity value between a document and the query, the higher the similarity value of a document with the query, the more relevant the document to the query. Calculating similarity between documents and query is done by dividing dot product of document vector and query vector with multiplication of Euclidean value of document vector and Euclidean value of query vector. Euclidean value is calculated by finding out the square root of the sum of the squared term weight in documents. The calculation is as the followings (4).

$$sim(d_i,q) = \frac{\vec{v}(d_i)\cdot\vec{v}(q)}{|\vec{v}(d_i)||\vec{v}(q)|}, |\vec{v}| = \sqrt{\sum_{i=1}^{M} \vec{v}_i^2(d)} \quad (4)$$

H. Calculation of Term Weight of Expansion Result

This stage adds the calculation by using IDF value of each document term of search result since the term from expansion result of query has lower degree of importance compared to that from original query. Documents containing term from original query can have higher similarity compared to those with term from expansion result. This research used calculation based on the reference as shown in (5) [23] [24].

$$sim = Cosim + \sum_{i=1}^{n} \begin{cases} 1 & ,Term = QA \\ 1-\left(\frac{1}{log(dfi)}\right) & ,Term = QE \\ 0 & ,df(QE) \leq 10 \end{cases} \quad (5)$$

Calculation is done by adding the calculation result of Cosine Similarity (Cosim) with value determined in (5). If number of term in a document is n original query term (QA), value of one (1) is added as many as n. If there is term from expansion result (QE) and df of QE > 10, so it is added 1 – (1/(log(dfi)). If df of QE ≤ 10, so it is added 0. The example of the calculation is as followings [25]:

Query: Sistem pakar penyakit tulang

Table II consists of expansion result from the tokenization of the query.

Table III consists of the calculation result of Cosine Similarity with the document.

The next is searching terms from the title of each document that intersect with original and expansion keywords in Table IV.

The intersected term results are then calculated by using equation (5) can be seen at Table V.

TABLE II. EXPANSION RESULT

Original Keyword	Expansion Keyword
Sistem	*Acara, aturan, bentuk, cara, jalan mekanisme, metode, mode, peraturan, proses, tata, teknik, system*
Pakar	*Ahli*, expert, *juru, spesalis*
Penyakit	*Kelainan, kesulitan, masalah, problem*
Tulang	-

TABLE III. CALCULATION RESULT OF COSINE SIMILARITY

ID	Title	Cosim Value
053/INF/ 2009	*Sistem Pakar Untuk Mendiagnosa Penyakit Tulang*	**0.2148**
047/TINF/ 2012	*Pemanfaatan Multimedia Dalam Sistem Pakar Untuk Mendiagnosa Penyakit Tulang*	**0.1841**
144/INF/ 2006	*Sistem Pakar Berbasis Web Untuk Diagnosa Penyakit Tulang Pada Manusia Menggunakan Metode* Certainty Factor	**0.1625**

TABLE IV. TERM SEARCHING

ID	Term Preprocessing	Explanation
053/INF/ 2009	*sistem*	Original Keyword
	pakar	Original Keyword
	diagnosa	-
	sakit	Original Keyword
	tulang	Original Keyword
047/TINF/ 2012	*manfaat*	-
	multimedia	-
	sistem	Original Keyword
	pakar	Original Keyword
	diagnosa	-
	sakit	Original Keyword
	tulang	Original Keyword
144/INF/ 2006	*sistem*	Original Keyword
	pakar	Original Keyword
	basis	-
	web	-
	diagnosa	-
	sakit	Original Keyword
	tulang	Original Keyword
	manusia	-
	metode	Expansion Keyword
	certainty	-
	factor	-

TABLE V. INTERSECT TERM RESULT

ID	Term Preprocessing	DF	Score	Total
053/INF/ 2009	*sistem*	961	1	4.0000
	pakar	127	1	
	sakit	148	1	
	tulang	5	1	
047/TINF/ 2012	*sistem*	961	1	4.0000
	pakar	127	1	
	sakit	148	1	
	tulang	5	1	
144/INF/ 2006	*sistem*	961	1	4.8837
	pakar	127	1	
	sakit	148	1	
	tulang	5	1	
	metode	409	1-(1/log(409))	

Total of intersected term calculation result of each document is then summed with Cosim value of each document from Table VI.

The calculation result above is the new value of document similarity calculation.

TABLE VI. INTERSECT TERM CALCULATION RESULT

ID	Title	Final Value
053/INF /2009	*Sistem Pakar Untuk Mendiagnosa Penyakit Tulang*	0.2148 + 4.0000 = **4.2148**
047/TINF/ 2012	*Pemanfaatan Multimedia Dalam Sistem Pakar Untuk Mendiagnosa Penyakit Tulang*	0.1841 + 4.0000 = **4.1841**
144/INF/ 2006	*Sistem Pakar Berbasis Web Untuk Diagnosa Penyakit Tulang Pada Manusia Menggunakan Metode* Certainty Factor	0.1625 + 4.8837 = **4.9963**

I. Recall, Precision and Non-Interpolated Average Precision (NIAP) Testing

Effectiveness of information retrieval system is the ability measurement of system to retrieve a variety of documents from database in accordance with the user's request. There are two critical things usually used in measuring ability of information retrieval system, namely ratio or comparison of recall and precision. Recall and precision calculation are calculation done to a group of documents from search result (set based measure) in overall, so it cannot describe the performance of information retrieval system in terms of relevant document ranking [2]. NIAP is used to check the search success of software developed [26].

Testing is done for 50 times for each of those with spelling correction and query expansion and those without them for testing the relevance level of document search results retrieved by system. Formula for recall, precision and NIAP are shown in (6), (7) and (8).

$$recall = \frac{\#(relevant\ items\ retrieved)}{\#(retrieved\ items)} \tag{6}$$

$$precision = \frac{\#(relevant\ items\ retrieved)}{\#(relevant\ items)} \tag{7}$$

$$NIAP = \frac{1}{\#relevant\ items} \times \left(\sum_{d_i \in relevant}^{n} \frac{i}{Rank\ (d_i)}\right) \tag{8}$$

III. METHOD

This research has two critical processes, namely storage and search processes.

The storage process stores data of documents consisted of id, title, year of publication, and author into document table. Then, the title of document is extracted. Term of the document title is taken for TF-IDF weighting and a group of words from documents title is taken for synonym table formation. Fig. 3 shows flow of storage process.

Document search processes consist of correction process of keywords from user's query by using Levenshtein Distance, query expansion based on synonym table formed, relevance calculation by using Cosine Similarity, and expansion term weighting process to add to relevance value of Cosine Similarity calculation result. Fig. 4 shows flow of document search process.

A. Data Collection

Dataset used in this research is in the forms of titles in excel file format containing research document titles. Data of the scraping results consist of 2,083 records with four attributes, namely ID, title, author, and year.

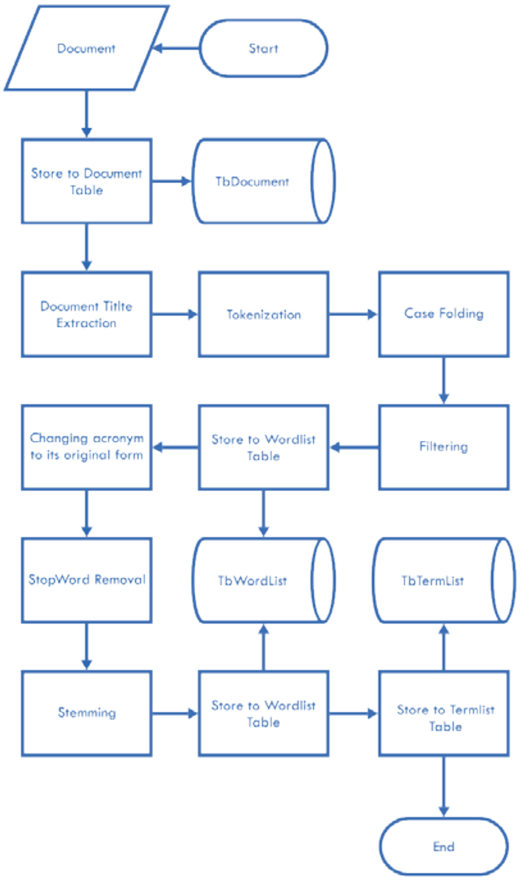

Fig. 3. Flow of Data Storage Process.

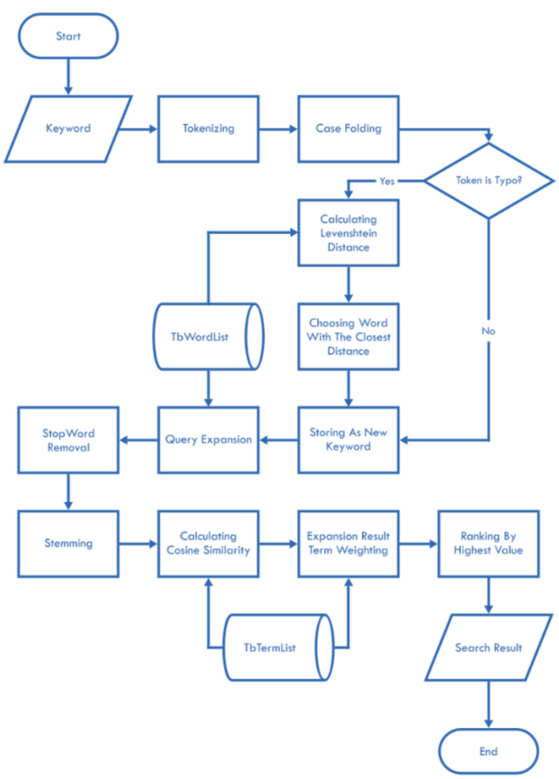

Fig. 4. Flow of Document Search Process.

IV. RESULT AND DISCUSSION

Testing is done for 50 times by using data of 2,045 document titles in database with different keywords in every testing both with the use of spelling correction and query expansion on query keywords or not.

A. *Testing without Spelling Correction and Query Expansion*

This testing only uses similarity calculation with Cosine Similarity without spelling correction and query expansion on keywords to compare recall and precision value with those with spelling correction and query expansion. In Table VII, it can be seen that several rows have errors in keyword writing which finally the Rt value = 0 and also follows the recall value, precision and NIAP = 0. Writing errors can be seen in the blocked rows, such as in the 3, 4, 5, 8, 11, 17 and so on. Various writing errors are such as missing letters, excessive letters and letter placement errors. This testing obtains average recall of 69.11%, precision of 69.28%, and NIAP of 60.72%.

TABLE VII. SEARCHING RESULT WITHOUT SPELLING CORRECTION AND QUERY EXPANSION

No	Keyword	#Rt	Recall	Precision	NIAP
1	klasifikasi	25	48.08%	100.00%	48.08%
2	pencarian	39	78.00%	100.00%	78.00%
3	levemstein	0	0.00%	0.00%	0.00%
4	roshio	0	0.00%	0.00%	0.00%
5	steganogarfi	0	0.00%	0.00%	0.00%
6	multimedia	209	100.00%	100.00%	100.00%
7	aplikasi	161	100.00%	100.00%	100.00%
8	autocorect	0	0.00%	0.00%	0.00%
9	fuzzy	33	100.00%	100.00%	100.00%
10	bayes	61	100.00%	100.00%	100.00%
11	medfia pembelaaran	0	0.00%	0.00%	0.00%
12	klasifikasi c45	5	83.33%	100.00%	83.33%
13	teknologi informasi	22	100.00%	54.55%	61.95%
14	pengolahan citra	5	100.00%	100.00%	100.00%
15	sistem informasi	438	98.61%	97.03%	97.26%
16	web service	30	93.75%	100.00%	93.75%
17	algoritma steming	0	0.00%	0.00%	0.00%
18	kriptografi data	5	100.00%	100.00%	100.00%
19	keamanan komputer	1	100.00%	100.00%	100.00%
20	cosine similarity	0	0.00%	0.00%	0.00%
21	jaingan saraf tiruan	13	39.39%	100.00%	39.39%
22	vector space model	6	85.71%	100.00%	85.71%
23	sistem pencarian skripsi	12	100.00%	16.67%	54.17%
24	metode naive bayes	12	70.59%	100.00%	70.59%
25	lest significan bit	0	0.00%	0.00%	0.00%

26	pengembangan aplikasi mobile	16	94.12%	100.00%	94.12%
27	sistem pendukung keputusan	150	96.77%	100.00%	96.77%
28	sistem deteksi penyakit	5	7.04%	100.00%	7.04%
29	metode forwar chainng	0	0.00%	0.00%	0.00%
30	wireless application proocol	15	100.00%	100.00%	100.00%
31	sistem deteksi kemiripan dokumen	2	66.67%	100.00%	66.67%
32	perancangan sistem informasi web	2	100.00%	100.00%	100.00%
33	sistem pakar penyakit kanker	5	83.33%	100.00%	83.33%
34	metode simple additive weight	18	100.00%	94.44%	100.00%
35	sistem informasi akademik sekolah	6	60.00%	100.00%	60.00%
36	sistem deteksi penyakit tulang	9	100.00%	44.44%	95.00%
37	perancangan sistem informasi skolah	11	37.50%	27.27%	23.44%
38	media pembelajaran sekolah dasar	24	96.00%	100.00%	96.00%
39	sistem pendukung keputusan baiyes	150	100.00%	18.00%	25.31%
40	Sistem pakar metode naivebayes	49	100.00%	2.04%	3.03%
41	Pengembangan sistem berbasis web service	1	16.67%	100.00%	16.67%
42	sistem pendukung keputusan penentuan minat	1	100.00%	100.00%	100.00%
43	sistem pendukung keputusan naive bayes	1	100.00%	100.00%	100.00%
44	klasiifkasi dokumen skripsi naive baiyes	2	100.00%	100.00%	100.00%
45	analisis kinerja dosen naive bayes	1	100.00%	100.00%	100.00%
46	sistem pakar metode teorema bayes	4	50.00%	100.00%	50.00%
47	visualisasi distribusi term model vektor	1	100.00%	100.00%	100.00%
48	sistem pendukung keputusan analitical hierarcy proces	150	100.00%	9.33%	6.62%
49	sistem pakar diagnosa penyakit metode fuzy	8	0.00%	0.00%	0.00%
50	metode simple multi attribute rating technique	2	100.00%	100.00%	100.00%
	AVERAGE		**68.11%**	**69.28%**	**60.72%**

B. Testing with Spelling Correction and Query Expansion

This testing uses similarity calculation with Cosine Similarity and spelling correction on keywords with Levenshtein Distance algorithm followed with query expansion. This testing obtains average recall of 95.91%, precision of 63.82% and NIAP of 86.29%. In Table VIII it can be seen an increase in recall value, this is due to the improvement of keywords in several tests that have writing errors. The RT value was previously 0 in Table VII changes depending on the data in the database. In the correction keyword column, the rows that are blocked are spell-checked words and produce the appropriate words so that they can be found in the database. For example: "levemstein" becomes "levenshtein", "roshio" becomes "rocchio", "steganogarfi" becomes "steganography" and so on.

TABLE VIII. SEARCHING RESULT WITH SPELLING CORRECTION AND QUERY EXPANSION

No	**Correction Keyword**	**#Rt**	**Recall**	**Precision**	**NIAP**
1	klasifikasi	159	100.00%	32.70%	64.96%
2	pencarian	142	100.00%	35.21%	85.50%
3	levenshtein	1	100.00%	100.00%	100.00%
4	rocchio	1	100.00%	100.00%	100.00%
5	steganografi	13	100.00%	100.00%	100.00%
6	multimedia	209	100.00%	100.00%	100.00%
7	aplikasi	497	100.00%	32.39%	87.24%
8	autocorrect	1	100.00%	100.00%	100.00%
9	fuzzy	33	100.00%	100.00%	100.00%
10	bayes	61	100.00%	100.00%	100.00%
11	media pembelajaran	195	100.00%	84.62%	100.00%
12	klasifikasi c45	12	100.00%	50.00%	100.00%
13	teknologi informasi	51	54.55%	23.53%	35.88%
14	pengolahan citra	16	100.00%	31.25%	100.00%
15	sistem informasi	750	98.61%	56.67%	85.64%
16	web service	30	93.75%	100.00%	93.75%
17	algoritma stemming	4	80.00%	100.00%	80.00%
18	kriptografi data	27	100.00%	18.52%	100.00%
19	keamanan komputer	1	100.00%	100.00%	100.00%
20	cosine similarity	14	100.00%	100.00%	100.00%
21	jaringan saraf tiruan	33	100.00%	100.00%	100.00%
22	vector space model	8	100.00%	87.50%	98.21%
23	sistem pencarian skripsi	44	100.00%	4.55%	19.61%
24	metode naive bayes	49	82.35%	28.57%	76.91%
25	least significant bit	12	92.31%	100.00%	92.31%
26	pengembangan aplikasi mobile	19	100.00%	89.47%	99.67%
27	sistem pendukung keputusan	172	100.00%	90.12%	100.00%
28	sistem deteksi penyakit	96	100.00%	73.96%	80.66%

29	metode forward chaining	20	100.00%	5.00%	50.00%
30	wireless application protocol	15	100.00%	100.00%	100.00%
31	sistem deteksi kemiripan dokumen	4	100.00%	75.00%	100.00%
32	perancangan sistem informasi web	49	100.00%	4.08%	41.67%
33	sistem pakar penyakit kanker	48	100.00%	12.50%	85.42%
34	metode simple additive weighted	19	100.00%	89.47%	100.00%
35	sistem informasi akademik sekolah	29	100.00%	34.48%	85.67%
36	sistem deteksi penyakit tulang	39	100.00%	10.26%	88.75%
37	perancangan sistem informasi sekolah	30	50.00%	13.33%	54.57%
38	media pembelajaran sekolah dasar	46	96.00%	52.17%	91.52%
39	sistem pendukung keputusan bayes	94	100.00%	28.72%	84.27%
40	sistem pakar metode naivebayes	1	100.00%	100.00%	100.00%
41	pengembangan sistem berbasis web service	10	66.67%	40.00%	41.67%
42	sistem pendukung keputusan penentuan minat	84	100.00%	1.19%	100.00%
43	sistem pendukung keputusan naive bayes	19	100.00%	5.26%	100.00%
44	klasifikasi dokumen skripsi naive bayes	2	100.00%	100.00%	100.00%
45	analisis kinerja dosen naive bayes	2	100.00%	50.00%	100.00%
46	sistem pakar metode teorema bayes	4	50.00%	100.00%	50.00%
47	visualisasi distribusi term model vektor	1	100.00%	100.00%	100.00%
48	sistem pendukung keputusan analytical	12	85.71%	100.00%	85.71%
49	hierarchy process	23	100.00%	30.43%	54.90%
50	sistem pakar diagnosa penyakit metode fuzzy	2	100.00%	100.00%	100.00%
	AVERAGE		**95.91%**	**63.82%**	**86.29%**

Search results with keyword correction have higher average recall and precision value than those without keyword correction even though each trial has same keywords. The reason is that the use of Levenshtein Distance algorithm can correct some typo-indicated keywords correctly, so that system can find documents that have the keywords.

Fig. 5, Fig. 6, and Fig. 7 show comparison of recall, precision and NIAP value based on the number of term.

Fig. 5 shows that recall value of testing with spelling correction and query expansion is higher than that without them. The reason is that the use of spelling correction can display documents with typo-indicated keywords while the use of query expansion can find documents that have similar meaning with keywords from user's query.

Fig. 6 shows that precision value of testing with spelling correction and query expansion tends to be lower than that without them. The reason is that query expansions on keywords are too general; as a result, some documents that are less relevant are also displayed.

NIAP value in Fig. 7 shows the excellence of testing with spelling correction and query expansion compared to that without them. The reason is that the use of query expansion can display relevant documents that have similar meaning with keywords from the query and the ranking result is above the documents that are less relevant based on Cosine Similarity and term weighting of query expansion.

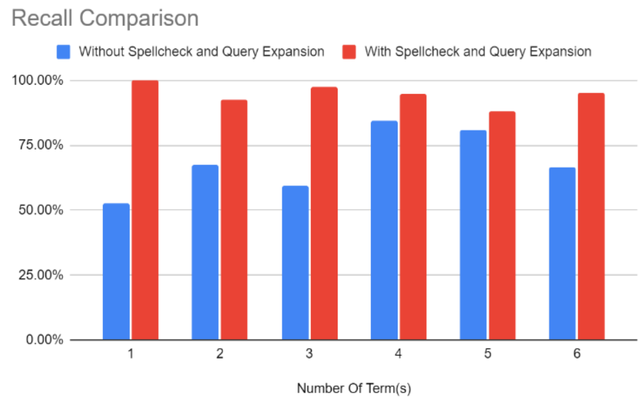

Fig. 5. Comparison of Recall Value on Number of Term.

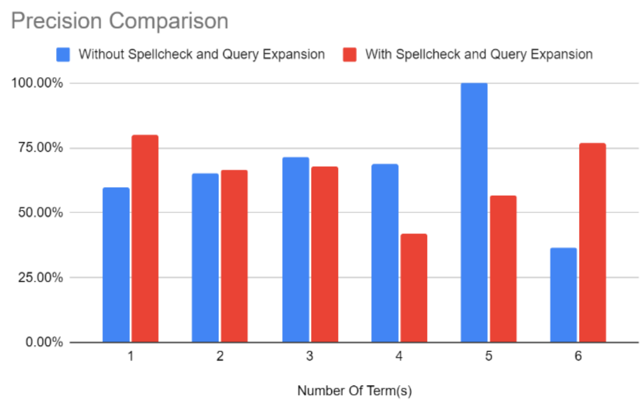

Fig. 6. Precision Comparison.

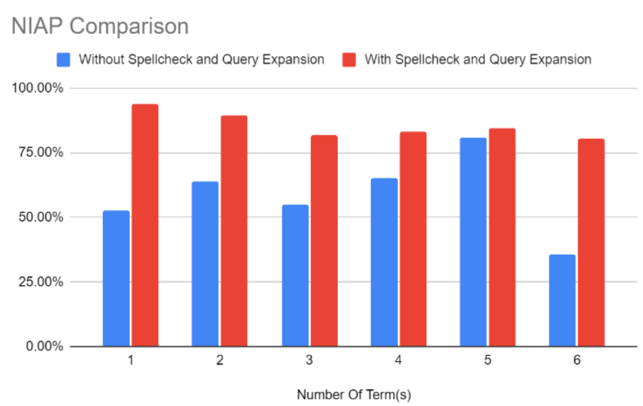

Fig. 7. NIAP Comparison.

V. Conclusion

Hybrid spelling correction and query expansion on keywords are able to improve relevance of document searching. The reason is that the use of spelling correction can display documents with typo-indicated keywords while the use of query expansion can find documents that have similar meaning with keywords from user's query. The proposed methods are able to improve relevance of document searching with average recall from 68.11% to 95.00%, but the precision decreases from 69.28% to 63.32%. However, the decrease does not influence the ranking of relevant documents retrieved by system because there is an increase of NIAP value from 60.72% to 86.29%, so the low precision is tolerable.

VI. Future Work

This research can be further developed by optimizing algorithm to correct typo-indicated keywords, so it can correct typo-indicated keywords based on the linkages of the keywords in query and not only based on their Levenshtein Distance. Besides, query expansion can be optimized in finding synonym of keywords, so term of expansion results are not too wide and to add feature to find expansion results of phrases, so it is not limited to only term from user's query. Therefore, the recall value can increase without lowering the precision value.

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Usability Perceptions of the Madrasati Platform by Teachers in Saudi Arabian Schools

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***Abstract*—As a result of the COVID-19 pandemic, the Saudi Ministry of Education launched the Madrasati Platform for distant teaching and learning for schools. Therefore, recognizing the design and the usability challenges that are linked to this new platform is significant. This paper reports the results of a study that examines the usability level of the Madrasati Platform from the perspectives of the schoolteachers in Saudi Arabia. It also investigates the usability issues that teachers faced when using the platform. A total of 759 teachers responded to the Computer System Usability Questionnaire (CSUQ). Semi-structured interviews were also conducted with ten teachers. The findings of the study indicated that the usability of the Madrasati Platform for the schoolteachers is inadequate and needs to be improved further. Navigation issues were the most reported issues by the participants. Finally, the paper presents some recommendations for improving the usability and experience with the Madrasati Platform.**

Keywords—Usability; Madrasati Platform; e-learning; Saudi Arabia; schools

I. Introduction

As information and communication technology has rapidly spread over the world, the internet has become an increasingly vital means of connection between educational institutions and their students. Schools, colleges, and universities are increasingly using e-learning as a teaching and learning tool. E-learning has numerous clear advantages over traditional learning methods, not the least of which is its flexibility to be used at any time and in any location. Furthermore, it creates environments that allow students to be active participants in their learning, to acquire independence, to become self-reflective, and to collaborate with others, as well as provide a lot of options for creative teaching approaches [1].

As a result of these advancements in internet technology, learning management systems (LMS) have emerged. LMSs are robust software platforms for managing educational activities, with the goal of assisting instructors in conveying knowledge to students and speeding up the learning process. LMSs can be used by educational institutions to store, administer, and distribute educational content as needed [2]. In recent years, a variety of learning management systems (LMS) have emerged, each with its own set of features and benefits for users. Blackboard (BB), Desire2Learn (D2L), and Moodle are examples of learning management systems. By 2025, the global market for LMSs is expected to grow from 13.4 billion dollars in 2020 to 25.7 billion dollars [3].

There is an increasing recognition that high levels of usability are required for LMS development and application to be successful. Instructors save time with useable LMS because they can design and deliver courses more quickly and efficiently. Tutors and students can focus on course content rather than dealing with troublesome technologies, which improves the learning experience. Nonetheless, some studies suggest that the design of LMSs has received little attention, resulting in major usability issues [4]. As a result, institutions considering introducing any LMS must carefully examine its usability before deploying it.

As an emergency move to prevent the spread of the COVID-19 epidemic, schools and colleges around the world have closed face-to-face instruction and sent students home. Saudi Arabia, like many other countries across the world, employed remote learning via virtual classroom as a preventative step to protect teachers and students from COVID-19. In the face of COVID-19's rapid spread, schools were forced to choose between postponing lessons for an unknown period or introducing online classes right away [5]. Consequently, the Ministry of Education (MOE) established the Madrasati Platform, which is an LMS that facilitates teaching and learning in Saudi schools. It became obligatory for schools to use the Madrasati Platform to introduce courses. At the same time, teachers were learning how to use this platform. Traditionally, they had always used face-to-face instruction as a method of delivery. However, this transition to online learning has highlighted concerns about the quality of education [6].

Following the onset of COVID-19, this platform had just recently been adopted in Saudi Arabia's educational system so research on the platform's usability is limited. The author in [7] conducted the only study we found that evaluated the Madrasati Platform's usability. They evaluated the platform using different web diagnostic tools and measures and did not include any target groups of the Madrasati Platform such as schoolteachers and students. To the best of our knowledge, no studies have focused on evaluating the usability of the Madrasati Platform from the perspective of a target user of the platform as this study does; therefore, this study addresses the following research questions:

- Research Question 1 (RQ1): What is the usability level of the Madrasati Platform from the perspective of schoolteachers in Saudi Arabian?

- Research Question 2 (RQ2): What are the major usability issues that teachers faced when using the Madrasati Platform?

II. Literature Review

A. Covid-19 and Education in the Kingdom of Saudi Arabia

Saudi Arabian schools and universities have been forced to convert all their regular face-to-face classes to online classes as a result of the COVID-19 outbreak. Saudi Arabia's Ministry of Education made this decision on March 8, 2020. The Ministry responded to the closure decision by issuing a document called "The COVID-19 Pandemic Protocols" for universities to follow, in which online teaching became the primary form of instruction. Students were not permitted on campus, and no staff or faculty gatherings were permitted [8].

Since then, students and teachers have only been able to communicate via online platforms such as Blackboard and Zoom (an online video communications application). Thousands of teaching members were compelled to offer their lessons in front of a computer display, with students viewing from home using the internet. This significant transformation occurred in a short period of time. Due to the quick global development of COVID-19, the switch to online teaching was adopted in 61 more countries by March 13 [9].

Saudi Arabian universities have offered limited online education choices as part of an open education network since the early 2000s. Because the information and network technology infrastructure were not well developed, the number of online courses grew slowly over time. Furthermore, due to a lack of computer access for some students and inadequate computer skills among some faculty members, students and faculty members exhibited limited interest in online instruction [8]. Prior to the COVID-19 epidemic, the quantity of online courses compared to face-to-face courses was very low [10].

Shifting all current courses to online platforms in a matter of days was a significant issue. In addition, creating and delivering online courses involves precise lesson planning, specialized training, technology tools, and an IT team's help [8]. The unexpected breakout of COVID-19, on the other hand, revealed the lack of online teaching skills among faculty members as well as the unpreparedness for an entirely online approach among departments and schools. Students, on the other hand, showed fewer problems with online technologies and platforms, but they experienced issues with self-control, offline learning environments, and learning behavior [11], [12].

In Saudi Arabia, education is given a lot of attention and care by the government. Dr. Hamad bin Mohammed al-Sheikh, the Saudi Minister of Education, announced that Saudi Arabia began offering online education years ago, but the systems were recently updated in response to the coronavirus outbreak [13]. Since the start of this shift, the Ministry of Education (MoE) has introduced five virtual learning alternatives that could be accessed at any time and from any location. These are possibilities available to those who do not have access to the internet via television. Students can access their lectures via iEN TV channels, iEN's Youtube channel, iEN's educational portal, Future Gate, and the unified education database [14]. Moreover, the Ministry of Education has been broadcasting educational materials for all grades on television and through social media. Also, approximately 127 teachers and administrators have been nominated to teach regular classes in 112 enlightening courses on various television channels (broadcasting nationwide from a classroom in Riyadh) [15].

Furthermore, the Ministry of Education prepared to launch the new Madrasati Platform by the beginning of the 2020 academic year. The Madrasati Platform allows teachers to construct virtual classes and provide students with a wide range of content, including presentations, educational videos, textbooks, exercises, and courses at various levels: elementary, intermediate, and secondary [16]. The Ministry of Education has also created several educational policies to help students effectively utilize these electronic and educational opportunities. For example, morning hours are allocated to intermediate and secondary students, while afternoon hours are allocated to elementary students, so that parents would be able to follow up with the students to provide help with their distant learning in the evening [17]. Al Mayman points out that the MoE is working closely with other ministries to ensure that every student has the necessary tools and resources to successfully complete the school year via distant learning. The objective is to assist students who lack internet access, or who do not have any devices to access the platform by broadcasting lessons during school time [16].

AlSalih points out that the Ministry of Education is working in cooperation with experts in international organizations to conduct an extensive validating assessment study on distant learning in universities and schools, during and after the pandemic [18]. Therefore, online learning is not just a temporary solution for this period. The Saudi Minister of Education has declared that online learning could eventually become a strategic choice for Saudi Arabia and not just an alternative in response to the coronavirus crisis [19].

Many studies have evaluated the effect of COVID-19 on education in Saudi Arabia [8], [15], [20]. In a study conducted in Saudi Arabia's elementary schools, researchers investigated the teachers and the students' perspectives of e-learning. Overall, teachers and students in primary schools expressed positive attitudes toward e-learning [20]. Another study conducted in Jubail Industrial College reported that E-learning according to many teachers, saves time and energy when it comes to revising and modernizing teaching materials. A small percentage of teachers consider e-learning to be an additional liability because they are not confident in their capacity to handle the technical needs during the pandemic. The majority of teachers were enthusiastic about the idea of incorporating new technologies and approaches into the classroom. Teachers, on the other hand, pointed out that proper training and workshops are essential to improve the effectiveness and efficiency of e-learning activities [15].

B. Madrasati Platform

As abovementioned, the Madrasati Platform was established by the Ministry of Education (MoE) as a result of the decision by the Saudi government to close all public schools in the country. Originally, the schools were to use the Madrasati Platform for the first seven weeks of the first semester of the 2020 academic year. As the coronavirus situation continued, the MoE announced that schools are to continue using the platform until further notice. The Madrasati Platform is an e-learning environment consisting of many tools that support the teaching and learning process for all education levels from the 1st to the 12th grade. It also helps in following the lesson plans and achieving educational aims and objectives set by the curriculum. Furthermore, it aids students in acquiring skillsets, values and new knowledge, and at the same time being compatible with the digital needs and requirements of the present and future [21].

The Madrasati Platform features a package of educational tools to assist the teaching and learning process. The platform features a virtual classroom that enables teachers and students to meet via virtual conference or at any suitable time via recorded lessons. In addition, it includes the Microsoft Office (365), which includes email client, Teams, and a variety of networks for communication amongst learners, teachers, or parents. The platform also provides educational books, videos, and cartoons, containing 450,000 electronic lesson plans and 45,000 educational contents. Moreover, it contains tools related to lesson planning and design that allow teachers to design lessons with equality and diversity in mind. Teachers can also design assignments or online tests using this platform. The platform also has test-banks that contain in excess of 100,000 questions for evaluation and measurement of cognitive and educational achievements [21], [22].

By the end of the first semester in 2020, the Madrasati Platform facilitated more than 89,000 virtual lessons for private and public schools in Saudi Arabia, with about 489 million visitors. Moreover, teachers created more than 2.5 million electronic test forms using this platform during the first semester, while students submitted more than 15 million assignments and made more than 10 million enquiries to teachers [23].

Madrasati's features and performance are quite similar to those of commercial providers like Moodle, Blackboard, and Canvas. Madrasati Platform, on the other hand, is an internally built LMS that is designed by an organization rather than one that is purchased and deployed by a commercial company.

Khanfar (2020) investigated the most significant obstacles encountered by female teachers in Eastern Region public schools in Saudi Arabia during the coronavirus pandemic. She concluded that the most important challenges were the skills and the infrastructure required in using the Madrasati Platform based on 375 female teachers' opinions [5]. However, as discussed above, the Madrasati Platform incorporates a variety of Microsoft Teams features which enables safe virtual classrooms for learners to interact with their teachers when it comes to class homework and e-activities [21]. In another study, [22] concluded that most teachers believed that the platform would reduce the teachers' responsibilities in future, especially in theoretical materials, and hoped to continue teaching using this platform even after the coronavirus pandemic has ended. The teachers also reported that due to the difficulties during the registration process, some students and teachers were hesitant to use the platform when it was first introduced [22].

Moreover, the teachers also indicated that using the Madrasati Platform has many advantages such as ease of teaching, an integrated platform, online tests and assignments. The platform also saves time, effort, and data; builds learners self-reliance; reduces financial waste, and traffic congestion. Nonetheless, the Madrasati Platform also has several disadvantages and negative aspects, including less interaction, no direct communication between teacher and student, and a decrease in students' attention levels and lack of flexibility in tackling them. Also, there is the issue of evaluating outstanding students, which led them to decide not to attend the asynchronous virtual classroom (iEN channels or other recorded video) and only concentrating on synchronously virtual (live) classroom on Teams. Finally, there are some technical issues with the suspension of the platforms' system [22].

C. *Usability of e-Learning*

According to [24] and [25], current e-learning systems are more concerned with the course material than with the design of the content. The majority of e-learning research studies focus on the information quality rather than the design's usability [26], [27]. The main problem faced by e-learning designers is the creation of sophisticated technologies that allow learners to easily endure their learning activities regardless of time or location [28]. According to [29], the interface is the most important aspect in the user's first impression.

Human-Computer Interaction (HCI) is mostly accomplished using interfaces. This defines the e-learning tool's learning environment [28]. In the e-learning environment, interface design has an impact on the student and instructor's ability to collaborate effectively [30]. According to [31], usability is the most important component in HCI. The ability to use the system in a simple manner is referred to as usability [32]. Total usability, according to [33], is comprised of a few essential components, including learnability, efficiency, memorability, error frequency, and subjective satisfaction.

Perceived usability is an important component of the higher-level construct of us-ability [34]–[37]. The Computer System Usability Questionnaire CSUQ [38] and the System Usability Scale [39] are two of the most widely used standardized questionnaires for assessing perceived usability. They were created independently in the 1980s by IBM and DEC and released in the mid-1990s. According to recent studies, the SUS and CSUQ questionnaires are highly associated and appear to be assessing the same thing, probably perceived usability [40], [41].

Many studies on evaluating usability of e-learning websites have been undertaken in Saudi Arabia [42]–[45]. For example, Al-Omar (2017b) investigated and assessed the internal and exterior usability aspects of 12 university websites in Saudi Arabia that offer distant education courses and found that these websites are reliable but violate basic usability criteria. Also, [43] and [45] investigated the usability of JUSUR LMS using usability techniques based on satisfaction surveys. The findings revealed that the investigated students liked JUSUR LMS and found it simple to use. However, the system has some technical and functional issues that make it difficult to use. Moreover, [4] evaluated the design user interface to prove their hypothesis that Blackboard LMS is accessible and usable by teachers at King Saud University by questionnaires. The result was that the software is simple to access and use. Also, [46] recently published an empirical study in Saudi Arabia on Saudi students' preferences for Moodle and Blackboard systems. In their study, the authors compared three metrics: user interface, download and upload service, and materials organization. As a result, in terms of usability, students preferred the Moodle learning management system over Blackboard. Furthermore, a recent paper presented the findings of a study that investigated the usability of the Blackboard system from the perspective of academics at Umm Al-Qura University in Saudi Arabia, using two of the most used usability measures, SUS and CSUQ. The study's findings revealed that Blackboard's usability is insufficient and needs to be improved [40].

Furthermore, the content accessibility and usability of the Madrasti Platform were evaluated by [7]. In the examination, different web diagnostic tools and measurements based on Nielsen usability criteria were employed. The measures broke links compliance with WCAG guidelines. The evaluation was conducted on only 5 main pages in a student account which are the Sign in page, Home page, My courses page, My homework page and My schedule page. According to the findings, the Madrasti Platform is considered inaccessible by some disabled users. Also, the Madrasti's usability is considered as low [7].

III. METHODOLOGY

Both qualitative and quantitative data were collected in this study. As a result, both quantitative and qualitative approaches were used in the data analysis. This section will describe the methods used which are survey, semi-structured interview, and thematic analysis.

A. *The Questionnaire*

The study was conducted using the questionnaire as a data gathering tool. Questionnaires are one of the most used data collection techniques, across all fields of research, not just usability studies. The questionnaire was identified as the most appropriate for the study because large amounts of data could be collected in real time, it is familiar to several respondents, and it is easier to administer [47]. The questionnaire included 24 questions in three sections. The first section includes 4 questions that are related to age, gender, school level in teaching and region of the kingdom. The second section also includes 4 questions that related to teaching experience, whether an e-learning system has been utilized previously, device used and the internet browser. The third section of the questionnaire includes 16 questions (see Fig. 1) which are related to Computer System Usability Questionnaire (CSUQ). These questions produce four scores (one overall score and the other three are subscales). The following are the rules for determining these scores:

- Overall: average of the answers to questions 1-16 (all questions).
- The Usefulness of the System: average of the answers to questions 1–6.
- Information Quality: average of the answers to questions 7–12.
- Interface Quality: average of the answers to questions 13–15.

	The Computer System Usability Questionnaire Version 3	Strongly Agree						Strongly Disagree	
		1	2	3	4	5	6	7	NA
1	Overall, I am satisfied with how easy it is to use this system.	O	O	O	O	O	O	O	O
2	It is simple to use this system.	O	O	O	O	O	O	O	O
3	I am able to complete my work quickly using this system.	O	O	O	O	O	O	O	O
4	I feel comfortable using this system.	O	O	O	O	O	O	O	O
5	It was easy to learn to use this system	O	O	O	O	O	O	O	O
6	I believe I became productive quickly using this system.	O	O	O	O	O	O	O	O
7	The system gives error messages that clearly tell me how to fix problems.	O	O	O	O	O	O	O	O
8	Whenever I make a mistake using the system, I recover easily and quickly.	O	O	O	O	O	O	O	O
9	The information (such as online help, on-screen messages and other documentation) provided with this system is clear.	O	O	O	O	O	O	O	O
10	It is easy to find the information I needed.	O	O	O	O	O	O	O	O
11	The information provided with the system is effective in helping me complete my work.	O	O	O	O	O	O	O	O
12	The organization of information on the system screens is clear.	O	O	O	O	O	O	O	O
13	The interface* of this system is pleasant.	O	O	O	O	O	O	O	O
14	I like using the interface of this system.	O	O	O	O	O	O	O	O
15	This system has all the functions and capabilities I expect it to have.	O	O	O	O	O	O	O	O
16	Overall, I am satisfied with this system.	O	O	O	O	O	O	O	O

** The "interface" includes those items that you use to interact with the system. For example, some components of the interface are the keyboard, the mouse, the microphone, and the screens (including their graphics and language).*

Fig. 1. The CSUQ [36].

The resulting scores range from 1 to 7, or NA (not applicable), with lower scores indicating the higher agreement level of the user. The CSUQ scales had high reliability, with coefficient alphas exceeding .89 for all scales. [38], [40].

The respondents were given the questionnaire in their native language (Arabic). The Arabic version of the CSUQ was created using the translation approach as used by [48]. Google Forms was used to host the questionnaire online. The questionnaire was designed for teachers who were familiar with the Madrasati Platform in Saudi schools for all grade levels, as stated on the welcome page of the questionnaire. They were also informed that participation in the study was completely optional, and they could withdraw at any time. Also, to ensure clarity, three teachers piloted the questionnaire before it was distributed. After the questionnaire distribution, statistical analyses were conducted to analyze the data using the software - Statistical Package for the Social Sciences (SPSS).

B. *Semi-structured Interview*

Following the questionnaire, semi-structured interviews were conducted. They provided the flexibility we required for the interviews. They allowed us to focus on the most pressing usability issues about interface and design, as well as ask follow-up questions. As a result, we received detailed feedback on specific concerns. To recruit participants, we sent our request to find participants who had experience with the Madrasati Platform via social media tools such as WhatsApp and Twitter. Participants who were interested in being part of the study sent us their contact. We per-formed interviews until thematic saturation were reached [49], as the last few inter-views provided no new patterns or topics. A pilot study was conducted with one participant to ensure the clarity of the questions. As a result, the researcher decided to ask the participants to share their screen while using the Madrasati Platform which helped in providing more information about what the participants would like to express (see Fig. 2). All interviews were conducted online using Microsoft Teams. Each interview lasted between 40 minutes and one hour. To ensure consistency throughout all sessions, an interview guide was created. All participants gave their informed consent to be audio-recorded and participate in the study. The participants were given a brief explanation of the technique before the interviews began. The subjects discussed during the interviews were background information, teaching and technical experience, interface design issues, challenges, and suggestions for improvement. All the interviews were done in Arabic by the same inter-viewer, who wrote notes, audio-recorded and transcribed the conversation. The transcript was translated to English and reviewed by two linguistic experts (English and Arabic).

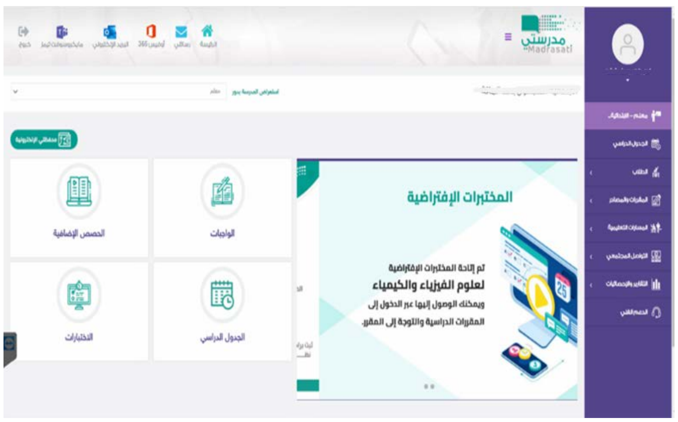

Fig. 2. A Screenshot of the Madrasti Platform from a Teacher Account.

C. Thematic Analysis

The researcher used Braun and Clarke's thematic analysis approach (see Table I) to analyze the qualitative data [50]. A method for detecting, analyzing, and reporting patterns (themes) within data is thematic analysis [50]. The thematic analysis was conducted using Nvivo, a qualitative data analysis software tool.

The researcher familiarized herself with the data by looking over it twice and collecting notes in the first step of the analysis. The noteworthy features in data were coded in a systematic manner across the full data set in the second stage, and data relevant to each code was gathered. The third stage was to group the codes into possible topics. According to [51], researchers should code 10–50 percent of the data first, and then have another coder confirm the coding reliability. The researcher used this suggestion to examine 25% of the data and create early coding groups and definitions. After then, the data was given to an independent coder to double-check. The independent coder had prior qualitative coding experience but had no prior knowledge of the subject. The researcher and the independent coder reviewed the themes in the fourth step to make sure they functioned with the coded extracts and the whole data set. After that changes were made to improve the coding scheme. The researcher continued to code the rest of the data after refining the technique. The topics were given names and descriptions in the fifth step. A scholarly report on the analysis was created as the final phase. The independent coder then double-checked all the segmentations and coding. Both the researcher and the independent coder collaborated to discuss and resolve issues, as well as to come up with the final category names.

TABLE I. THEMATIC ANALYSIS'S PHASES [50]

1.	Familiarization with the data
2.	Generating initial codes
3.	Searching for themes
4.	Reviewing themes
5.	Defining and naming themes
6.	Producing the report

IV. RESULTS

The results of the questionnaire and the interviews are presented in this section.

A. Participants

A total of 759 participants responded to the questionnaire and 20% of them were male while 80% were female. 12.6% were between the ages of 26 and 35; 35.1% were between the ages of 36 and 45; 32.4% were between the ages of 46 and 55; and 1.6% were beyond 55. In addition, most of the participants (71.3%) had teaching experience of more than 10 years. 42% were teaching the primary level, 26.6% were teaching the intermediate level, 24.6% were teaching the secondary level and 6.4% were teaching more than one level. Also, 37.7%, 34.8% and 7.9% of the participants were from Riyadh region, Makkah region and Madinah region, respectively. Moreover, 61.5% of participants reported that they never been utilized any e-learning systems previously. Furthermore, Google Chrome was the browser used with the Madrasati Platform by 64% of the participants. 20.7% used Microsoft Edge and 7.8% used Safari. Finally, 552 teachers (72.7%) used the Madrasati Platform via laptops, 10.3% via tablets or iPads, 11.9% via mobiles and only 5.1% via desktops. Table II provides an overview of the descriptive statistics of the participants.

For the interviews, it was conducted with ten teachers who agreed to participate with ages ranged from 34 to 45 years. 70% of the interviewees had a bachelor's degree, 20% had a master's degree and 10% had a diploma. Moreover, 40% of interviewees were teaching the secondary level, 30% were teaching the primary level, and 30% were teaching the intermediate level. Also, 80% of the interviewee had a teaching experience of more than 10 years.

B. CSUQ

Fig. 3 shows the average response to each item in the CSUQ questionnaire from all participating teachers. Numbers range from 1 to 7, with lower scores indicating a higher satisfaction level. The average of teachers replies to the statements range between 2.61 and 3.97. The overall score of the CSUQ, as well as the scores of the three subfactors: System Usefulness, Information Quality, and Interface Quality, are shown in Fig. 4. The CSUQ's overall score was 3.14 (SD = 1.97) and the three subfactors had average scores of 2.83, 3.41, and 3.25, respectively.

TABLE II. SUMMARY STATISTICS ON PARTICIPANT DEMOGRAPHICS

Demographic Attributes		Number of respondents	%
Gender	Male	152	20
	Female	607	80
Age	<25	2	.3
	26–35	96	12.6
	36–45	403	53.1
	46–55	246	32.4
	>55	12	1.6
Teaching Experience	<1	2	.3
	1 year> and <5 year	31	4.1
	6 years> and <10 year	185	24.4
	10 years >	541	71.3
School level	Primary	322	42.4
	Intermediate	202	26.6
	Secondary	187	24.6
	> level	48	6.4
Region:	Riyadh	286	37.7
	Makkah	264	34.8
	Eastern	46	6.1
	Madinah	60	7.9
	Al Baha	2	0.3
	Qassim	33	4.3
	Ha'il	1	0.1
	Tabuk	30	4.0
	Aseer	14	1.8
	Jazan	22	2.9
	Najran	1	0.1
Previously Use E-learning System	Yes	292	38.5
	No	467	61.5
Browser	Google Chrome	486	64
	Microsoft Edge	157	20.7
	Safari	59	7.8
	Firefox	18	2.4
	internet explorer	20	2.6
	Other	19	2.5
Device For Platform Use	Desktop	39	5.1
	Laptop	552	72.7
	Tablet/iPad	78	10.3
	Mobile	90	11.9

In order to determine the level of satisfaction, CSUQ scores were transformed to a 0–100-point scale from their previous scale of 1-7. This conversion is used in previous studies [40], [41] to convert CSUQ scores to SUS scores then the scores were matched against the Sauro–Lewis CGS (Table III). The process of this conversion is as follows:

- Taking the mean of the CSUQ items (16 separate items).
- minus 1, and.
- multiplying by 100/6.
- subtracted the result from 100.

For example: Using the best possible CSUQ mean of 1, the score converted to the SUS scale is: 100 – (1–1) (100/6) = 100–0 = 100.

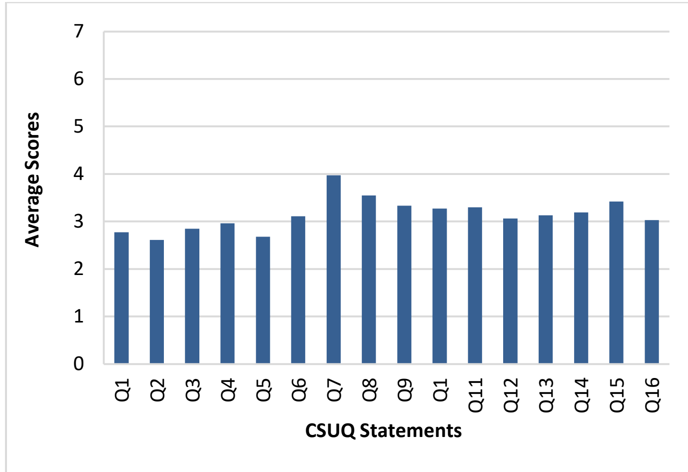

Fig. 3. Statement-by-Statement Comparison of CSUQ.

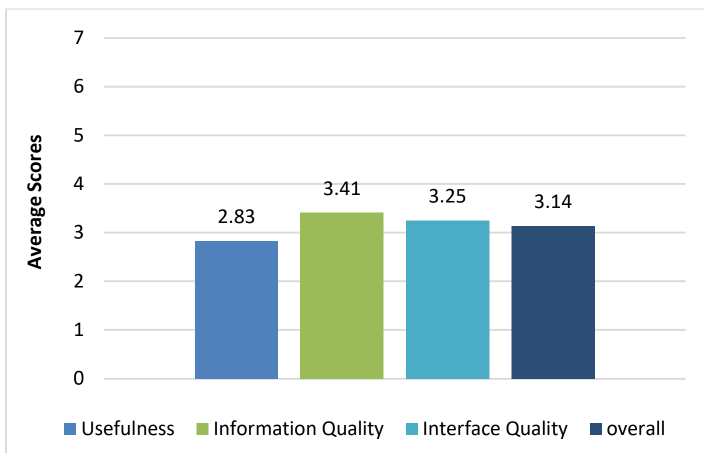

Fig. 4. Overall Score of CSUQ and the Three Scores of CSUQ Subfactors.

Table IV shows the converted scores for the CSUQ (overall and the three subfac-tors). The overall mean CSUQ was 64.36 (Grade: C-) which indicates that the Madrasati Platform has a low average of usability and teachers were not entirely satisfied with it. The converted scores for both Information Quality and Interface Quality are low (Grade: D) while the score of the Usefulness is within the average (Grade: C).

TABLE III. THE SAURO–LEWIS CURVED GRADING SCALE

SUS score range	Grade	Percentile range
84.1–100	A+	96–100
80.8–84.0	A	90–95
78.9–80.7	A –	85–89
77.2–78.8	B+	80–84
74.1–77.1	B	70–79
72.6–74.0	B –	65–69
71.1–72.5	C+	60–64
65.0–71.0	C	41–59
62.7–64.9	C –	35–40
51.7–62.6	D	15–34
0.0–51.6	F	0–14

TABLE IV. CONVERTED SCORES FOR THE CSUQ (OVERALL AND THE THREE SUBFACTORS)

factor	Mean	Score range	Grade
overall	3.14	64.36	C-
Usefulness	2.83	69.51	C
Information Quality	3.41	59.80	D
Interface Quality	3.25	62.52	D

C. Themes

Table V shows the number of usability issues reported by interviewees. In total, 135 issues were reported. Seven themes emerged from the thematic analysis of the interviews. Table VI describes how each theme in this study is defined. 28.15% of the issues were about navigation theme and 26.67% were about missing features. Furthermore, 20%, 11.11% and 8.15% of the issues were about broken features, compatibility issues and system messages' issues, respectively. The lowest percentage of the issues was about inability of the platform to prevent errors with 4.44% and accessibility with 1.48%.

Missing Features: All the ten interviewees proposed features that were missing but may help them use the Madrasati Platform more effectively. Features and example quotes include the following:

1) Assignment notification: "When students submit their assignments, they notify me with their submission via WhatsApp because there are no assignments notifications in the platform." User4.

2) Synchronize the Madrasati Platform with the Noor system: "After we finish, we need to insert all grades in "Noor" system. Why is there no link between the two systems? It is double works for us." User2.

3) Download all files: "It is better if the platform provides the option to download all assignments as one file or a compressed file." User9.

4) Message status Read/Unread: "When I go to the students' inquiries page, I don't remember which messages I read and which ones I didn't. There is no message status (read and unread) and this makes me check all messages each time." User1.

5) Share questions with other schools: "There is no questions bank for my course, and I wish that I could share questions with other teachers who are teaching the same course in other schools. This will save our time." User7.

6) Sort Assignments: "When I view students' assignments, I cannot sort them as what I need. It displays Assignments based on alphabetic of students' names. I would like to sort them based on the submission date." User8.

7) Submit project: "There is no option for students in the secondary level to submit their projects and we use Telegram for this." User6.

8) Search filter by date in attendance report page: "In attendance report, I cannot search by date or by the class, only search by status is available." User3.

9) Synchronize the Madrasati Platform with Microsoft Team: "Taking attendance for each class is exhausting and it is hard especially when I have two continuous classes. Why the platform is not linked with Teams and can take the attendance automatically." User9.

10)Charts and Graphs: "The report pages not comfortable to our eyes because all statistics are represented as numbers and texts. It is too much information here. Using charts and graph is preferable." User10.

11)Help and support documents: "The platform lacks help documents, if I faced any problem; I go to YouTube to see what people who have the same problem do." User5.

12)Save Session: "When I start to prepare the session and I go to add assignment and come back to my session again. I do not find it because there is no save session option, so I have to recreate it again." User7.

TABLE V. NUMBER OF THEMES EMERGED BY EACH USER

Themes	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10	Total	%
Missing features	2	3	5	3	4	3	4	5	4	3	36	26.67
Broken features	3	1	3	2	2	2	5	2	3	4	27	20
Navigation	3	2	6	2	3	3	4	3	5	7	38	28.15
Accessibility.	0	2	0	0	0	0	0	0	0	0	2	1.48
Preventing errors	1	0	2	2	0	0	1	0	0	0	6	4.44
Compatibility	1	1	3	3	2	1	1	0	2	1	15	11.11
System Messages	3	3	1	2	1	0	1	0	0	0	11	8.15
Total of the issues	**13**	**12**	**20**	**14**	**12**	**9**	**16**	**10**	**14**	**15**	**135**	**100**

TABLE VI. THEMES' DEFINITIONS

Theme	Definition
1) Missing features	Users face difficulties due to the absence of certain functions
2) Broken features	Users face difficulties due to some current functions not working, provide inaccurate result or cause delay in work.
3) Navigation	Users have difficulty moving between pages or selecting appropriate links for information or function.
4) Accessibility.	Users with disabilities have difficulty contributing, perceiving, comprehending, navigating, and interacting with the platform.
5) Preventing errors	Users find the platform not helping them from prevents a problem from occurring in the first place.
6) Compatibility	Users face difficulties when using specific browser or specific device.
7) System Messages	User experienced unclear, wrong or useless error message. Also, user does not receive a message or feedback when it is required.

Broken Features: All the ten interviewees mentioned problems with the Madrasati Platform's present features. Some of the current features, such as motivational stars, grades, and academic records, are not working. Other features, such as system email, announcements, and a short time for automatically logging out, caused them to experience delays. Other issues were mentioned, such as lost assignment files and inaccurate teacher reports. Examples of quotes that mention those issues are as follows:

- "Teacher report is not accurate, and this is really annoying me because I add a lot of things, but the number in the report is not correct. I take pictures for what I did and send it to the leader of the school because she asks me about it, and she cannot see my efforts via the platform". User9.
- "The auto logout is short and if have two continuous classes, I have to login twice." User3.
- "If I add enrichments in enrichments' bank, it does not appear in the class, but it is counted in the report. And if I add it from my Timetable, it appears in my class but not counted in the report. So, I have to add it twice in the two places to make sure it will appear in both my report and my class." User10.

Navigation: The Madrasati Platform was difficult to navigate for all the ten interviewees. There were complaints about being unable to return to the previous page, duplications, and seeing assignments one by one. The concerns are described in the following quotes:

- "I can send assignment to students from two places. From my timetable and from my assignments. This is really confusing." User7.
- "Back button is missing from many pages, and each time I have to click the main menu to go to the page that I want." User10.
- "It is really hard viewing assignment one by one. I have six classes and each class has 40 students. I send assignments twice a week and downloading assignments one by one is time consuming." User9.
- "When I download the student's assignment, the file name is not meaningful and not related to students. So, when I need to find the specific student assignment, I have to navigate all of them." User3.

Accessibility: One teacher mentioned the content accessibility issues in the Madrasati Platform with her students who have a hearing impairment. The teacher mentioned the videos with no subtitles, sign language, or a summary. Examples of quotes that mention this issue are as follows:

- "In our school we have special classes for hearing impairment students. We summarize the content for them not like other students. But in the Madrasati Platform, the same content for all, even the videos there is no written summary next to them that can help those students." User2.
- "The cartoon films without subtitle or the use of sign language. Thus, students go to Ein channel which has all videos in sign language". User2.

Preventing errors: Four teachers shared examples of how the Madrasati Platform failed to prevent faults or mistakes from occurring. Drop down menus that are not synchronized, manual calculations, and duplicate sessions are all examples of issues. Examples of the quotes that mention this issue are as follows:

- "When I select the level in the first dropdown menu, I can select a course for another level from the next dropdown menu. In the second dropdown menu, I'm supposed to see only the courses related to the level that I have selected in the first dropdown menu." User1.
- "I have to calculate the number of minutes when I create the exams or session. It is better if the platform calculates it to avoid any mistakes or at least to give us another option like choose hours." User3.
- "I can create the same session twice and this caused a lot of delay in waiting to move students to one of them." User4.

Compatibility: Nine teachers mentioned cases related to this theme. The Madrasati Platform was difficult to use via Google Chrome compared to other browsers. Also, some problems were mentioned when using mobile phones or tablets. The issues are described in the following quotes:

- "We prefer to use Google Chrome, but we had a problem with it. It keeps saving the data and we cannot use different accounts even when delete the data. To solve this problem, we create many accounts in the same laptop, one for me, one for my husband and one for our son and one for our daughter." User4.
- "I usually use Google Chrome but with the Madrasati Platform, I found that Microsoft Edge is better. I faced many problems with Google Chrome, the system hangs a lot with it" User2.

- "I cannot use specific types of questions like matching question. It will not work effectively in mobile or tablets." User5.

System Message: Six teachers expressed issues with the system's messages and responses. Some error messages were unclear, there was no system reaction, and there was a lack of problem explanation in the message. The concerns are described in the following quotes:

- "The system shows me errors in creating assignment, but I don't know what the reason is or how I can solve it. I only try again and again." User1.
- "I have uploaded the file, but no message tells me its uploaded. Then, when I refresh the page, the file is there." User7.
- "I found that if I uploaded a large image, the message does not tell me you uploaded a big file and by guessing I know that this is the reason." User4.
- "Some error messages have ambiguous codes, and I don't understand it." User3.

V. Discussion

This section discusses the study's findings, as well as their relevance to other studies. The goals of this study were to determine the usability of a Madrasati Platform from the perspective of schoolteachers in Saudi Arabian, as well as to identify the most common usability concerns that teachers encountered when using the platform.

The first research question aims to investigate how teachers perceived the Madrasati Platform in terms of usability. A total of 759 teachers from different regions in Saudi Arabia responded to the CSUQ in our study. The CSUQ's mean total score was 64.63, which was lower than expected. Based on this finding, it seems that the usability of the Madrasati Platform on the teacher side is inadequate and needs to be improved. Comparing this result with the findings of the study with the Madrasati Platform in a different context, it is consistent with the research of [7] which reported that students' pages in the Madrasti Platform had several issues in terms of usability. Looking to the three subscales of the CSUQ, the results show that the acceptable mean score for the Usefulness while the scores are lower than expected for both Information Quality and Interface Quality. These findings are similar to the results of [40] when evaluating the usability of the Blackboard using CSUQ.

The second study question was to determine the most significant usability concerns that teachers had when using the Madrasati Platform. Teachers found the Madrasati Platform difficult to navigate. There were concerns about inability to access the previous pages and many duplications. Navigation is a critical issue and requires more considerations which have an impact on user satisfaction and continuity with e-learning systems [52]. Comparing this result with the findings of previous research in a different context, it is consistent with the research of [40] which found that the navigation is a significant issue on the Blackboard by the instructors. Teachers in our study also complain about functions that are not working. As previously stated, the system was developed throughout the epidemic, and the Ministry of Education made numerous updates and improvements during that time [53]. Working on the system for such a short period of time may not be sufficient to carefully test the functionalities that have been reported as broken. Furthermore, teachers mentioned other usability difficulties, such as the platform's inability to prevent them from making mistakes and issues with the platform's messages and responses. Unclear error messages, a lack of problem explanation in the message, and manual calculations that allow for human error are just a few examples. This result is in line with [54] which examined the usability of Khan Academy and found the major issues in "Error Prevention" when the system does not prevent users from making errors and users don't get properly informed in the state of error. Moreover, the Madrasati Plat-form's content accessibility concern for students with hearing impairment was identified. Subtitles, sign language, and videos brief summaries are not supported on the Madrasati Platform. This finding is consistent with prior research by [7], who found that the Madrasti platform is inaccessible to some disabled users. Based on the findings, the present study's recommendations for enhancement are as follows:

- It is necessary to conduct extensive testing of the platform's functions, and bro-ken features should be marked as inactive.
- It is advised to connect the Madrasati Platform to the Noor system to assess students immediately.
- Madrasati Platform developers are encouraged to follow the World Wide Web Consortium (W3C) guidelines to ensure that people with disabilities have the same access to information on the platform as everyone else.
- Access to the previous and next pages should be made easier for the user. Adding "Back" and "Next" buttons, for example, will be beneficial.
- The Madrasati Platform should offer appropriate help online and provide documentation that is easily accessible and searchable.
- It is suggested to reduce the amount of text in the page by using graphs and charts in the statistical and reports pages.
- It is recommended to include sign language in the content provided by a video and to employ cartoon films with subtitles. Also, next to each video, include a summary in writing.
- It is suggested to integrate the Teams program and Madrasati Platform. As a result, student attendance and absence records on the Platform will be immediately linked to the Teams program.
- Eliminate redundancy on the platform whenever possible to reduce cognitive overload and confusion.
- A database for scientific material, such as assignments and tests, should be available.

- Replace human calculations with system calculations and synchronize corresponding dropdown menus to prevent users from selecting the incorrect option.
- it is recommended that the platform should not use jargon in messages to pro-vide clear and understandable helping messages.
- The number of clicks required to access any page should be kept to a minimum. For example, send assignment button can be added in the create assignment page.
- It is advised to increase the duration time for the automatically logout.
- It is essential to enhance the search by adding common search features and filters.
- Allow users to download all files at once to save time downloading large numbers of files one at a time.
- Adding features such as assignment notification, sort assignment, share question with other schools, message status and submit project will be useful.
- Continuous user feedback will improve Madrasati Platform's usability and acceptability in schools.

The outcomes of this study contribute to the fields of e-learning system and usability evaluation in a variety of ways. The research provided here is the first to assess Madrasati Platform's perceived usability from the perspective of schoolteachers and make recommendations based on the findings. The findings have significant implications for e-learning system usability. It will aid the Saudi Ministry of Education in developing policies and programs that will ensure the success of e-learning in the kingdom.

VI. Limitations

It is important to mention that generalizability of the findings has limitations. First, the participants of the study were all recruited from a single target group: teachers. While this has not hampered our research because they are one of the primary target groups for the system being examined, it may limit the applicability of the findings to other groups who use it. Second, the data collecting methods in this study were a standardized usability questionnaire and semi-structured interviews. It would be interesting to know if data gathered from traditional usability research showed consistent results. Third, the study was conducted during the pandemic since the Madrasti Platform is still new to most teachers and they are unfamiliar with it. The results may change when teachers become more familiar with the platform.

VII. Conclusion

The Madrasati Platform is a new system for all school levels in Saudi Arabia that was developed by the Saudi Ministry of Education during the covid-19 pandemic. Usability is one of the most important characteristics of a system since it affects how users interact with it. Therefore, in this paper, we examined the usability level of the Madrasati Platform from the perspective of schoolteachers in Saudi Arabia, as well as the most common usability difficulties that teachers encountered when using the platform. Both questionnaires and semi-structured interviews were conducted to collect the data. According to the study's findings, the Madrasati Platform's usability in schools for teachers is insufficient and should be improved further. Teachers stated many usability issues faced by using the Madrasati platform such as navigation, broken features, inability of the platform to prevent user mistakes to occur, message error issues, compatibility issues and content accessibility issues for the disability users. Additionally, a list of recommendations for enhancement was presented based on those findings. For future work, evaluation of the Madrasati Platform's usability with other target groups, such as students, school leaders, and parents, is helpful. Also, examine into whether the demographics of users have an impact on the total CSUQ scores. Furthermore, combination of evaluation methods, such as focus group, heuristic evaluation, and eye tracking, would be useful. Moreover, examination of other usability factors, such as memorability, learnability and accessibility, would be valuable in the future.

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IDD-HPO: A Proposed Model for Improving Diabetic Detection using Hyperparameter Optimization and Cloud Mapping Storage

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Abstract*—Readmission to the hospital is an important and critical procedure for the quality of health care as it is very costly and helps in determining the quality level of the point of care provided by the hospital to the patient. This paper proposes a group model to predict readmission by choosing between Machine Learning and Deep Learning algorithms based on performance improvement. The algorithms used for Machine Learning are Logistic Regression, K-Nearest Neighbors, and Support Vector Machine, while the algorithms used for Deep Learning are a Convolutional Neural Network and Recurrent Neural Network. The reasons for the appearance of the efficiency of the model depend on the are preparation of correct parameters and the values that control the learning. This paper aims to enhance the performance of both machine learning and deep learning based readmission models using hyperparameter optimization in both Personal Computer environments and Mobile Cloud Computing systems. The proposed model is called improving detection diabetic using hyperparameter optimization , the proposed model aims to achieve the best rate of between prediction rate accuracy for hospital readmission at the same time minimizing resources such as time delay and energy consumption. Results achieved by proposed model for Logistic Regression, K-Nearest Neighbors, and Support Vector Machine are (accuracy=0.671, 0.883, 0.901, time delay=5, 7, 20, and energy consumed=25, 32, 48) respectively, for Recurrent Neural Network and Convolutional Neural Network are (accuracy=0.854, 0.963, time delay=25, 660 energy consumed=89, 895) respectively. However, this proposed model takes a lot of time and energy consumed especially in Convolutional Neural Network. So, the experiments were conducted again, but in the cloud environment, based on the existence of two types of storage to preserve the accuracy but decreasing time and energy, the proposed model in cloud environment achieve for Logistic Regression, K-Nearest Neighbors, and Support Vector Machine (accuracy=0.671, 0.883, 0.901, time delay=2, 3, 8, and energy consumed=8, 9, 11) respectively, for Recurrent Neural Network, Convolutional Neural Network (accuracy=0.854, 0.963, time delay=15, 220, and energy consumed=20, 301) respectively.

Keywords—Machine learning; deep learning; diabetes; hospital readmission; hyper parameter optimization; cloud computing; mobile cloud computing

I. Introduction

With the change of lifestyle and the massive expansion in many countries, diabetes, which is considered a chronic and non-communicable disease, has become one of the most deadly diseases. Despite this, many deaths can be prevented through data analysis [18]. Therefore, in most developing countries, diabetes is a primary health care concern, the healthcare sector collects and processes medical data for diabetic patients in huge quantities of diverse sizes and structures [19].

The meaning of readmission to a hospital is the time it takes for the patient to return to the hospital again. Hospital quality is measured and health care costs are reduced by measuring readmission hospitals are financially penalized for exceeding the permitted rate of 30-day readmissions [21]. Machine Learning (ML) algorithms can be used to create objective models which then can be used to measure risk. These models are more complex but may be able to create more accurate risk predictions that should lead to improved diabetic patient outcomes [20]. Deep Learning (DL) algorithms have recently attracted a lot of interest in educational circles and commercialism because of their effective impact in various fields of research, such as speech recognition, natural language processing, and brain computer interface [16].

When creating ML and DL algorithms, there are many possibilities to define the architecture of the learning model. Often, the optimal model architecture for a given model is not known, and thus a range of possibilities must to be able to explore. In the way of ML and DL, the machine is asking to perform this exploration and automatically determine the optimal model structure. The parameters that define the structure of the model are referred to as hyperparameters [13], hence the process of searching for the ideal structure of the model is referred to as hyperparameter optimization [27].

Despite all this, ML and DL face an important challenge, as the performance of the algorithm depends heavily on its choice of parameters. DL requires hyperparameter optimization more than ML because (1) DL has more hyperparameters to be optimized, (2) DL has a higher dependency on the configuration of hyperparameters.

The accuracy of using deep learning changes drastically from 32.2% to 92.6% due to the variable selection of hyperparameters as reported [17]. Therefore, an effective hyperparameter optimization method is necessary for ML and DL.

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Other models used different ML and DL algorithms with different preprocessing methods but could not predict readmission for diabetic patients with high accuracy, nor did it take into account the point of saving resources such as reducing the time and energy consumed in the prediction process.

The goal of the paper is to 1) develop an accurate and generalized machine learning and deep learning models that is applicable to predicting 30-day readmission for diabetic patients by using hyperparameter optimization to control learning of machine; 2) to demonstrate the efficiency of (IDD-HPO) in mobile cloud computing environment with saving resources to minimize the total cost; 3) compare (IDD-HPO) results with the results of state-of-the-art models.

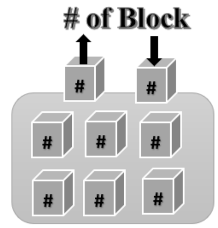
II. Background

Cloud Computing (CC) has recently emerged as a new framework to facilitate and implement online services [22], storing, analyzing, and displaying data requires significant modifications to the current cloud model, which in turn requires financial constraints and computational cost [23,24]. Many CC platforms provide these web services for ML and DL. The most popular of these are Amazon Web Services, Microsoft Azure, Google Cloud, and IBM Cloud [25]. Cloud storage is the online storage of data on the cloud. The data on the mobile is sent and stored in the cloud, the mobile device can access this data any time anywhere by sending data requests.

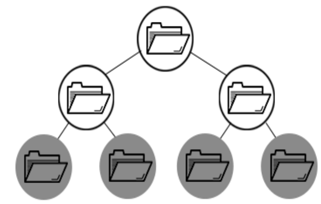
The two most common technologies of the system cloud storage are block-level storage and file-level storage. These two storage levels are described as follows [26]:

Block-level storage: Data is stored in blocks on a device with fixed sizes for each block (e.g., 512 Bytes). Data is stored according to the data format, type of ownership for each block, data stored as blocks in hard drives, which are installed in remote storage, a request is sent from the filing system to the storage this request is responsible for writing data to certain blocks and then retrieve it as shown in Fig. 1(a). Block storage is built to simplify larger workloads and improve Input/Output Operations per Second (IOPS), they are apt to be more expensive than file storage systems. However, this seriously depends on the chosen seller, conditions, features, cost of the storage operating system (OS), and some other variables.

File-level storage: Simply having an efficient, easily reached, and existing location to store files and data folders continues to be the most important requirement of any organization. For file-level storage, the only thing that is required is having a location to unload the data as shown in Fig. 1(b). File storage is stores data in a hierarchical architecture so the data and its metadata are stored in the form of files and folders. File storage systems are usually less costly than block storage. However, this seriously depends on the chosen seller, conditions, features, cost of the storage operating system (OS), and some other variables.



(a) Block-level Storage.



(b) File-level Storage.

Fig. 1. Types of System Cloud Storage.

This paper proposes a model with the objective of predicting diabetic readmission rate in hospitals, this model is named “Improving Detection Diabetic Using Hyperparameter Optimization” ((IDD-HPO)) by using ML algorithms (e.g., Logistic Regression (LR), K-Nearest Neighbors (KNN), and Support Vector Machine (SVM)) and DL algorithms (e.g., Convolutional Neural Network (CNN), Recurrent Neural Network (RNN)) for predicting hospital readmission among diabetics using hyperparameter optimization method in two scenarios, the first in personal computer (anaconda 3) and the second in the cloud environment.

This paper aims to: Improving the prediction of readmission to hospitals using hyperparameter optimization for both ML and DL algorithms. These prediction models are tested in two environments: personal computer and mobile cloud computing MCC system. The aim of these models is to achieve the best performance with high accuracy and decreasing total cost (e.g. time delay and energy consumed) based on mapping storage in the cloud. As a case study, the proposed model ((IDD-HPO)) was applied in a personal computer and cloud computing system.

The rest of this paper is organized as follows; the next section presents some related works. Then the proposed method will present in Section III. Subsection A in Section III presents the dataset description, subsection B presents the details of Machine Learning and Deep learning models tuning Using Hyperparameter Optimization, subsection C presents the details of the Cost Model for sending and receiving data to/from a server, and subsection D presents the details of the proposed Improving Detection of a Diabetic using Hyperparameter Optimization (IDD-HPO) model. Section IV presents the experiments for (IDD-HPO) on Personal computer system, subsection B presents the experiments for (IDD-HPO) on MCC system, subsection C presents the Comparative analysis Against State-of-the-Art Models with Results. Finally, conclusion and future works.

III. Related Work

In the field of health care, readmission to the hospital is considered a high priority because it represents whether the hospital is good or not, as it also aims to reduce costs. Little research has focused on readmission for diabetes, although diabetes on hospitalized patients has a large, growing, and costly burden.

In [2], this study was focused on the application of data mining techniques to predict the early hospital readmission by using ML algorithms, the most efficient algorithm was Random Forest with 0.898% of accuracy.

In this study [3], the prediction is done using Support Vector Machine (SVM), Random Forest (RF), Multilayer Perceptron (MLP), and Deep Neural Network if the discharged patient will be back in 30 days or not and the best presented accuracy value is 0.840%.

In [4], the model used in this study consists of 5 models tested and selected from 15 models. These blends are variables from logistic regression, decision trees, neural networks, and a naive Bayesian enhancer [5]. The performance of the model was on an unbalanced data set, and these models were selected after several tests and analysis of their accuracy, the accuracy value is 0.635%.

In [6], in the problem of readmission of diabetic patients to hospitals, the deep convolutional neural network (CNN) was used as an effective prediction method. This model is based on sample size scaling and data engineering processes. Using normalization is key to improving deep learning performance. This model achieves 92% better performance than other ML models.

In [7], Deep learning models (CNN, RNN) and machine learning algorithms (LR, KNN, SVM) were used to solve the problem of readmission of diabetic patients to hospital, this model is based on the use of data without normalization and the results were compared in the case of normalization and without normalization for (CNN, RNN, LR, KNN, SVM). The optimal performance in training and testing was in CNN in the case of using the data without normalization, where the accuracy ratio was achieved 0.924%.

In [8], the proposed Multilayer Perceptron model based on preprocessing process included comprehensive data cleaning, data reduction, and transformation aiming at better optimizing and selecting prominent features for 30-day unplanned readmission among diabetes patients. Random Forest algorithm is used for feature selection and SMOTE [9] algorithm for data balancing. a model consisting of two hidden layers with dropout [10] to achieve high overall accuracy and ROC. The proposed model with feature engineering is improving the performance of the others Machine learning algorithms, the accuracy value is 0.95%.

In [11], the researchers analyzed the readmission of diabetic patients using unsupervised methods and proposes an approach of generating embeddings for categorical features concatenated with normalized continuous features were fed into a neural network, the accuracy achieved is 0.952%.

In conclusion, most recent models relied on several methods for presenting data. These methods include: using Ensemble, normalization, non-normalization, Ensemble by age groups, and using data mining, all these methods do not achieve a high rate of accuracy. In this paper, the proposed model aims to use hyperparameter optimization methods to control the learning and evaluate the performance for the optimal values with the highest possible accuracy, but hyperparameters take a lot of time delay and energy consumed for the learning process. Hence the idea of using a hyperparameter in the cloud environment to reduce the time delay and energy consumed is proposed.

IV. The Proposed Method

This work proposes a model for improving the readmission rate. This model for improving detection of a diabetic using hyperparameter optimization ((IDD-HPO)) is implemented and compared in two environments: personal computers and cloud environment, then calculate accuracy, time delay, and energy consumed for each environment.

Fig. 2 summarizes the overall architecture of the proposed (IDD-HPO) model. In the following subsection, the model will be illustrate in more detail for each stage to build.

An intelligent model ((IDD-HPO)) based on hyperparameter optimization technique is proposed to enhance a choice between two classes (0, 1) where 0 is not readmitted and 1 is readmitted). Models used to apply ((IDD-HPO)) are CNN and RNN as DL algorithms and KNN, LR, and SVM as ML classifiers for the prediction of readmission.

In MCC, diabetes data set sent from mobile to cloud and retrieve from it to mobile based on the existing two levels of storage, file and block level.

The problem at the first applying ((IDD-HPO)) for data set in a personal computer system (anaconda3) and calculate the accuracy and total cost (time delay and energy consumed) for training and testing. Second applying ((IDD-HPO)) for data set in the cloud according to how to map mobile data item taking into account the limited resources of a mobile device by selecting the most suitable storage level for each data item to decreasing the time of training band testing for hyperparameter tuning and calculate accuracy and total cost (time delay and energy consumed).

In the rest of this section, the model is introduced then the (IDD-HPO) problem will be formulated.

A. *Dataset Description*

This proposed study is performed on a dataset represent 10 years (1999-2008) of clinical care at 130 hospitals across the United States and is provided by the Center for Clinical and Translational Research at Virginia Commonwealth University [1]. This data was used to predict the probability of readmission within the next 30 days for a patient with diabetes. The extracted information from the database for interviews must meet the following global criteria [14]:

1) All data taken during the meeting are from hospital cases.

2) Only diabetics are the ones to take data from at the meeting.

3) Range of stay patient in the hospital about 1-14 days.

4) Laboratory tests were carried out during the meeting.

5) Medicines were provided during the meeting.

101,766 encounters were identified to fulfill all of the above five inclusion criteria and were used in further analysis.

The data set was generated through three steps:

First, important features were extracted from the database. It was found that there were 55 features to be used in the study.

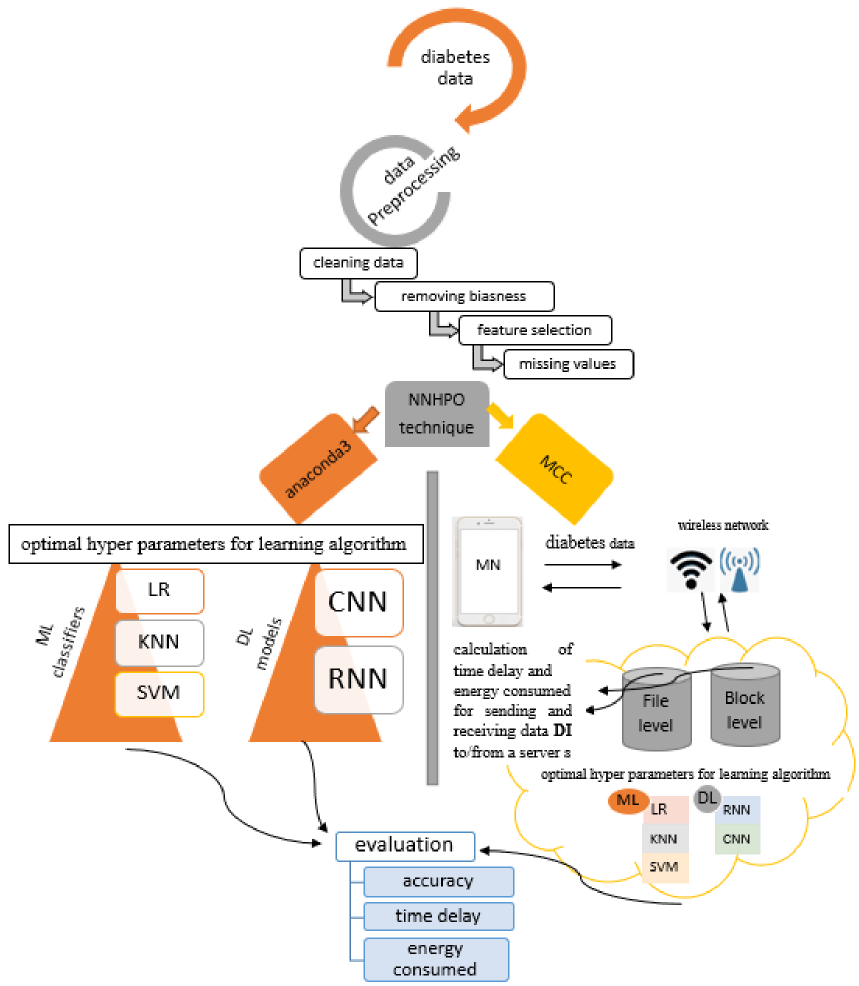


Fig. 2. The Proposed (IDD-HPO) Model in Personal Computer and MCC System.

Second, the data was preprocessed to extract useful information for research [11].

Third, the data set was upload to the cloud and store in two levels of storage file and block.

Data preprocessing will be implemented through the following steps:

- Cleaning Of Data: Firstly, delete records of patients who appear more than once to ensure that each patient has a unique identity. Then remove the features "patient_id,encounter_id" which tells about the Patient Number and Unique Identifier of a patient respectively.
- Removing Biasness: Also remove patient data dead or discharged to a hospice. Some rows are also repeat because the number of patients admitted within 30 days is very low.
- Feature Selection: There are a total of 55 features in this dataset, 23 of them medicine related features. After visualizing each other's dependency with the readmission feature found that the drugs the least role it plays in readmission, so 22 out of 23 medical features have been removed.
- Missing Values: Features that have a large percentage of missing values such as weight contain 97% so cannot be used in the analysis. So, the features with more than 30% missing values are removed. There is a feature, "medical specialty" that defines the specialty of attending physician which has some missing data so fill "Missing" in the missing place as this is the important feature for analysis. Then convert all the string categorical data into Integer categorical data to do analysis.
- Non-normalization technique: Data set will use without using any normalization. The advantage of the non-normalization technique is the facility to fix all features. It allows the classifier model to get the benefit of all features. Normalization is a packed down data between either -1 and 1 or 0 and 1. So data are need to use without any normalization to get correct output [7].

B. *Machine Learning and Deep Learning Models Tuning using Hyperparameter Optimization*

In ML and DL, the problem of selecting a set of optimal hyperparameters for a learning algorithm is hyperparameter optimization or tuning [10]. A hyperparameter is a parameter whose value is used to control the learning process and evaluates the problem to finding a set of optimal hyperparameters y* in the domain Y that return the best performance as evaluated on a validation set y:

$$y^* = \arg\min_{y \epsilon Y} f(y) \quad (1)$$

where the optimal solution is defined as the minimum of objective function *f*(*y*) that commonly corresponds to a loss function or an error rate.

The learning algorithm uses hyperparameters when it learns but it is not part of the resulting model. Parameters of the model have been trained which is effectively considered as a model at the end of the learning process, hyperparameters that were used during training are not part of this model. For example, the values of the hyperparameters that were used to train a model can not know from the model itself, the parameters of the model that were learned only know [12].

Tuning ML models is a kind of optimization problem. A set of hyperparameters exist and aim to find the correct combination of their values which can help us find the maximum (e.g. precision) of a function. For the proposed model, sets of ML and DL algorithms are used with different hyperparameters. The following is the list of used algorithms with their associated parameters.

- Logistic Regression (LR) tuning

Logistic regression does not contain any important hyperparameters to adjust. But sometimes, there are differences in performance with different solvers (*solver*).

- ➢ solver in [‘newton-cg’, ‘lbfgs’, ‘liblinear’, ‘sag’, ‘saga’].
- ➢ Regularization (*penalty*) can sometimes be helpful.
- ➢ penalty in [‘none’, ‘l1’, ‘l2’, ‘elasticnet’].
- ➢ The C parameter controls the penality strength, which can also be effective.
- ➢ C in [100, 10, 1.0, 0.1, 0.01].

- K-Nearest Neighbors (KNN) tuning.

The important hyperparameter for KNN is the number of neighbors (*n_neighbors*).

- ➢ Test values between at least 1 and 21.
- ➢ weights in [‘uniform’, ‘distance’]

- Support Vector Machine (SVM) tuning

There are a large number of hyperparameters in SVM algorithm to tune. For example, the parameter kernel will control how the input variables will be projected.

- ➢ kernels in [‘linear’, ‘poly’, ‘rbf’, ‘sigmoid’]

Another parameter that can take on a range of values is the penalty (C).

- ➢ C in [100, 10, 1.0, 0.1, 0.001]

- CNN and RNN Tuning

Grid Search and Random Search are applied for DL using Kera Classifier, it is possible to apply in the same way when using scikit-learn ML models. Some of CNN and RNN parameters will be optimized such as: how many epochs to use in each layer, the number of batch size, and which activation function and optimizer to use as shown in Fig. 3.

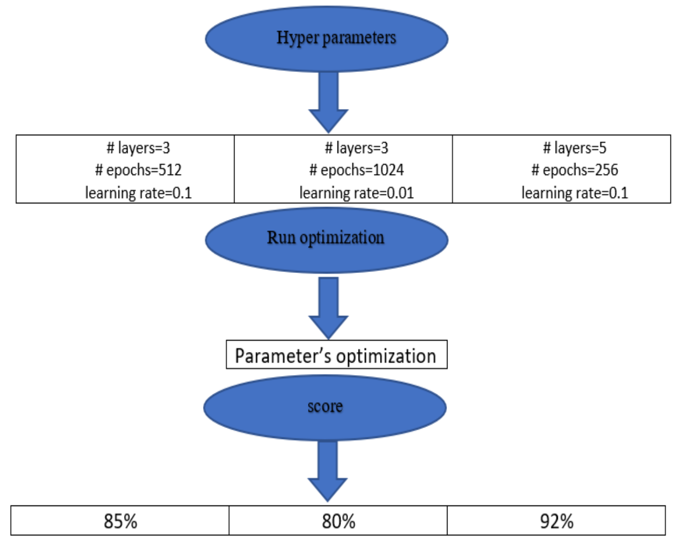


Fig. 3. CNN and RNN Hyperparameters.

C. *Cost Model for Sending and Receiving Data DI to/from a Server s*

In this subsection, the cost model is described for using the file and the block servers.

- Cost by using block cloud server

Block storage is built to simplify larger workloads, each data item needed to classify before storing it in the appropriate block. So, the cost for sending includes sending, classifying, and searching costs, and the cost for receiving includes retrieving and searching costs, they are apt to be more expensive than file storage systems. However, this cost depends on the chosen seller, conditions, features, cost of the storage operating system (OS), and some other variables.

- Cost for time delay in block cloud server

The cost of the time delay for sending DI to the block cloud server bcs is calculated as follows

$$CTD(S)_{bcs}(DI) = \sum_{d_i \epsilon DI} ctd_s(d_i, bcs) \quad (2)$$

The cost of the time delay for receiving DI to the block cloud server bcs is calculated as follows:

$$\mathrm{CTD(R)_{bcs}(DI)} = \sum_{\mathrm{d_i \epsilon DI}} \mathrm{ctd_r(d_i, bcs)} \quad (3)$$

By using Equations 2, and 3 the total cost for time delay by using bcs can be defined as follows:

$$\mathrm{TCTD_{bcs}(DI)} = \mathrm{CTD(S)_{bcs}(DI)} + \mathrm{CTD(R)_{bcs}(DI)} \quad (4)$$

- Cost for energy consumed in block cloud server

The cost of the energy consumed for sending DI to the block cloud server bcs is calculated as follows:

$$CEC(S)_{bcs}(DI) = \sum_{d_i \in DI} cec_s(d_i, bcs) \quad (5)$$

The cost of the energy consumed for receiving DI to the block cloud server bcs is calculated as follows:

$$CEC(R)_{bcs}(DI) = \sum_{d_i \in DI} cec_r(d_i, bcs) \quad (6)$$

By using Equations 5, and 6 the total cost for energy consumed by using bcs can be defined as follows:

$$TCEC_{bcs}(DI) = CEC(S)_{bcs}(DI) + CEC(R)_{bcs}(DI) \quad (7)$$

By using Equations 4, and 7 the total costs by using bcs is defined as follows.

$$TC_{bcs}(DI) = TCTD_{bcs}(DI) + TCEC_{bcs}(DI) \quad (8)$$

- Cost by using file cloud server.

File storage systems are usually less costly than block storage because the cost for sending includes sending without classification and searching costs and the cost for receiving includes retrieving and searching costs. However, this cost depends on the chosen seller, conditions, features, cost of the storage operating system (OS), and some other variables.

- Cost for time delay in file cloud server.

The cost of the time delay for sending DI to the file cloud server fcs is calculated as follows.

$$CTD(S)_{fcs}(DI) = \sum_{d_i \in DI} ctd_s(d_i, fcs) \quad (9)$$

The cost of the time delay for receiving DI to the file cloud server fcs is calculated as follows.

$$CTD(R)_{fcs}(DI) = \sum_{d_i \in DI} ctd_r(d_i, fcs) \quad (10)$$

By using Equations 9, and 10 the total cost for time delay by using fcs can be defined as follows.

$$TCTD_{fcs}(DI) = CTD(S)_{fcs}(DI) + CTD(R)_{fcs}(DI) \quad (11)$$

- Cost for energy consumed in file cloud server.

The cost of the energy consumed for sending DI to the file cloud server fcs is calculated as follows:

$$CEC(S)_{fcs}(DI) = \sum_{d_i \in DI} cec_s(d_i, fcs) \quad (12)$$

The cost of the energy consumed for receiving DI to the file cloud server fcs is calculated as follows:

$$CEC(R)_{fcs}(DI) = \sum_{d_i \in DI} cec_r(d_i, fcs) \quad (13)$$

By using Equations 12, and 13 the total cost for energy consumed by using fcs can be defined as follows:

$$TCEC_{fcs}(DI) = CEC(S)_{fcs}(DI) + CEC(R)_{fcs}(DI \quad (14)$$

By using Equations 11, and 14 the total costs by using fcs are defined as follows;

$$TC_{fcs}(DI) = TCTD_{fcs}(DI) + TCEC_{fcs}(DI) \quad (15)$$

D. (IDD-HPO) Proposed Model

The (IDD-HPO) model is used at the beginning with the ML classifiers (e.g., LR, KNN, and SVM), and DL algorithms (e.g., CNN, RNN), then the performance of (IDD-HPO) is measured by Accuracy, time delay, and energy consumed. Comparing it with the state of the art and proving the effectiveness of using (IDD-HPO) for diabetes data, (IDD-HPO) model is performed in a personal computer system (anaconda3) environment and both the time and energy consumed in the training and testing process are measured.

To reduce the time and energy consumption of (IDD-HPO) model in both ML and DL algorithms, the experiment environment is changed by using (MCC).

In a personal computer system (anaconda3) environment, the main goal of (IDD-HPO) model is using hyperparameters to control the learning process and evaluates the problem to finding a set of optimal hyperparameters that return the best performance as evaluated on a validation set.

In MCC, the main goals of (IDD-HPO) model are (1) minimizing the cost of time delay and energy consumed spent for sending and retrieving data. So, based on the previously described cost model in subsection C, the goal is finding the best cloud server (e.g. file cloud server (DI_{fcs}) or block cloud server (DI_{bcs})) to store data in the cloud. Such that no data item can be mapped to bcs and fcs at the same time. Then used a hyperparameter on the best cloud server controls the learning process and evaluates the problem to finding a set of optimal hyperparameters that return the best performance with the smallest time delay and energy consumed compared to time and energy on a personal computer.

To conduct training and testing in the cloud, depending on that the data is stored on the mobile, the data is sent from the mobile to the cloud and stored in the cloud depending on two types of storage, file, and block. The time and energy consumed in the process of storing data in each of the two types of storage (file and block) are calculated to determine the best type of storage according to the type of data used in the cloud. The time and energy consumed to conduct the training and testing process using (IDD-HPO) model are compared in both personal computer systems (anaconda3) and cloud computing environments. Here, MCC system model involves (1) mobile node, MN, (i.e., mobile device with a user) which has a set of data for diabetes $DI = \{d_i, 1 \leq i \leq n\}$, and each data item di represents different types of data (e.g., text, numbers, symbols, etc.). (2) a file cloud server, fcs, which stores all received data elements di from MN as files. (3) a block cloud server, bcs, which stores all received data elements d_i from MN as blocks. The energy consumed for sending and receiving a data item d_i to/from a server s are denoted as $cec_s(d_i; s)$ and $cec_r(d_i; s)$, respectively. Wheres can be a file server fcs or a block server bcs. Also, the time delay for sending and receiving a data item d_i to/from a server s are denoted as $ctd_s(d_i; s)$ and $ctd_r(d_i; s)$, respectively.

To improve the performance of the hospital readmission problem, the basic idea of (IDD-HPO) model is based on the following three issues: (a) using an (IDD-HPO) model for each model (ML, DL) in a personal computer and calculate the accuracy, time delay, and energy consumed. (b) estimating the total cost data sets DI on the file and block cloud servers by calculating their costs which were determined by using Equations (4,7,10,11). (c) comparing the calculated total costs and selecting the best appropriate mapping server based on the needs of a mobile user (e.g., minimum mapping costs).

The steps of these two cases are described as follows in Fig. 4 and 5.

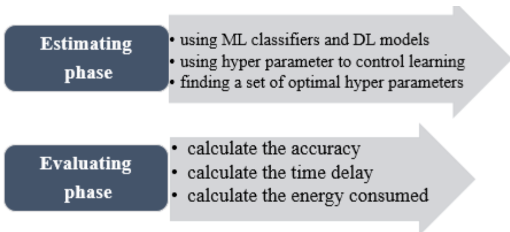


Fig. 4. Proposed (IDD-HPO) in Case 1 (a Personal Computer).

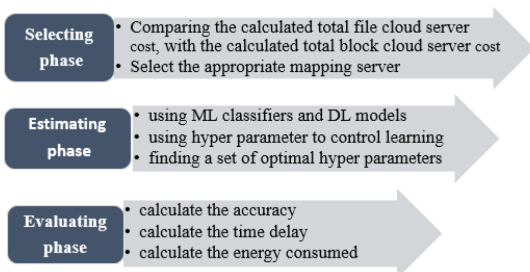


Fig. 5. Proposed (IDD-HPO) in Case 2 (MCC System).

V. Experimental Result

This section evaluates the performance of the proposed method for predicting hospital readmission using (IDD-HPO) model. through comparing it in two cases. The first one is when applying learning and testing for ML algorithms and DL algorithms in personal computers (anaconda3) with the state of the art, and calculate the time delay and energy consumed for (IDD-HPO) model. The second case is when applying learning and testing for ML algorithms and DL algorithms in the MCC system.

For the first experiment: (IDD-HPO) model with ML classifiers and DL algorithms, as the intelligent model, is built in Spyder Python 3.7 environment with processor intel(R) Core (TM), i5-2500 CPU @3.30 GHz.

For the second experiment: at the first the OMNet ++ [15] simulator was used to evaluate the best level of storage (e.g., fcs or bcs) for decreasing the total cost. Also, each experiment is repeated 5 times and the average was taken.

Then The (IDD-HPO) model is developed using Spyder python computing environment. Prediction models using (IDD-HPO) in the research were developed using the deep learning toolkit provided by the Anaconda software. The network configuration is initially determined based on the model that is built. The model is implemented on a GPU-enabled system with an Intel Core i7 processor with a capacity of 16 GB RAM.

CNN and RNN models are applied with one input layer, three hidden layers with uniform initialization, and one output layer. Softmax activation function was chosen for the output layer, while PRelu activation function was chosen for input layers. Added Dropout with rate=0.1 after hidden layers to limit overfitting and hence DL algorithms.

The selected optimization algorithms were [rmsprop, adam, sgd].

(IDD-HPO) model is used to find optimal hyperparameters (Table I). The classifiers with the optimal hyperparameters were tested on the holdout test set. This approach ensures that the training, validation, and evaluation data are completely separated.

A. *Experiments for (IDD-HPO) on Personal Computer System (Anaconda3)*

In this experiment, both ML classifiers against DL algorithms are used with (IDD-HPO) model. A hyperparameter is used to control the learning process and evaluates the problem to finding a set of optimal hyperparameters. For LR a hyperparameter (Regularization (*penalty*) is used to choose from the range [none, 11, 12, elasticnet], KNN a hyperparameter (Number of neighbors) is used to choose from the range [1-21], SVM a hyperparameter (kernels) is used to choose from the range [linear, poly, rbf, sigmoid], RNN hyperparameters (learning rate *lr* and Optimizer**)** are used to choose from the range [0.004, 0.008, 0.0012] and [rmsprop, adam, sgd] respectively, and CNN hyperparameters (epochs and batch_size) are used to choose from the range [50, 100, 150, 200] and [16, 32, 64] respectively. As shown in Table I.

TABLE I. (IDD-HPO) Model for ML and DL

Classifier	**hyperparameter**	**Range**	**optimal**
LR	Regularization (*penalty*)	[none, 11, 12, elasticnet]	none
KNN	Number of neighbors	[1–21]	3
SVM	kernels	[linear, poly, rbf, sigmoid]	linear
RNN	learning rate *lr*,	[0.005, 0.01, 0.015]	0.005
	the regularization coefficient λ	[0.004, 0.008, 0.0012]	0.004
CNN	Optimizer	[rmsprop, adam, sgd]	Adam
	epochs	[50, 100, 150, 200]	150
	batch_size	16, 32, 64	64

TABLE II. PERFORMANCE MATRIX FOR (IDD-HPO) IN A PERSONAL COMPUTER

Classifier	Accuracy for (IDD-HPO)	Time delay for (IDD-HPO)	Energy consumed for (IDD-HPO)
LR	0.671	5	25
KNN	0.883	7	32
SVM	0.901	20	48
RNN	0.854	25	89
CNN	0.963	660	895

Table II shows a comparison performance for ML and DL algorithms when used (IDD-HPO) model with test size 10. As shown in Table II the performance of DL algorithms is more accurate in predicting the use of ML. ML algorithms always need structured data, while DL networks rely on ANN (Artificial Neural Networks) layers. Therefore, the performance of DL was better as the data is not structured but it is multi-dimensional data. Also, time delay and energy consumed are calculated for training and testing both ML and DL algorithms.

Fig. 6, Fig. 7, and Fig. 8 show the accuracy, time delay, and energy consumed respectively for training and testing for Dl with (IDD-HPO) is very high compared to ML, where accuracy, time delay, and energy consumed to training and testing DL is (0.963%, 660 minutes, and 895 joules), respectively.

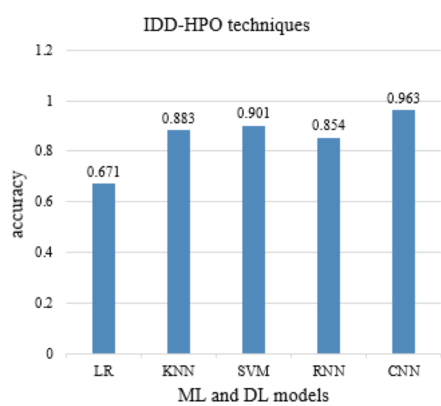


Fig. 6. Accuracy for (IDD-HPO) in Personal Computer.

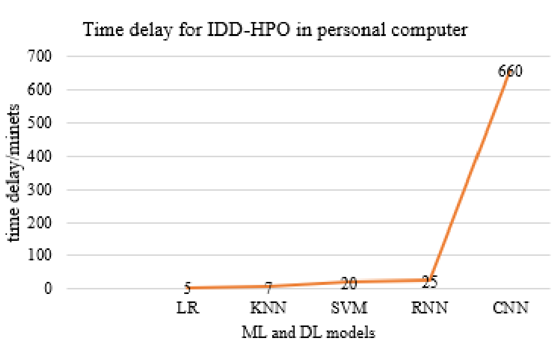


Fig. 7. Time Delay for (IDD-HPO) in Personal Computer.

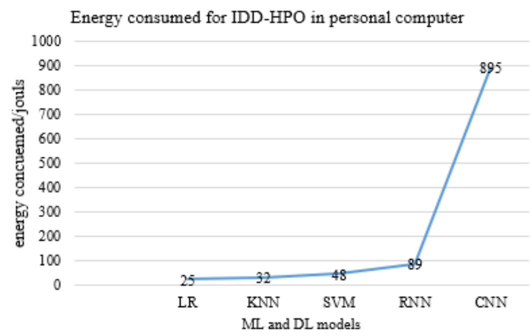


Fig. 8. Energy Consumed for (IDD-HPO) in Personal Computer.

B. Experiments for (IDD-HPO) on MCC System

The experiment is applying in a cloud computing environment so, at the first calculate the time delay and energy consumed for (IDD-HPO) model if data is store at the file and block cloud server.

Table III, shows the accuracy, time delay, and energy consumed for ML algorithms and the DL algorithms when used (IDD-HPO) model in fcs and bcs with test size 10. Also, time delay and energy consumed are calculated for training and testing both ML and DL algorithms if data is store in the cloud as fcs and bcs.

Fig. 9, and Fig. 10 show the comparing of the time delay and energy consumed respectively of using (IDD-HPO) model which is calculated by Equations 4, 7, 11, and 14 when training and testing are played in personal computer and MCC system using fcs and bcs. As shown in Fig. 10, and Fig. 11 The time delay and energy consumed of using (IDD-HPO) are decreasing if the data set is stored in the cloud as fcs against stored data in the cloud as bcs, and use (IDD-HPO) in a personal computer.

Fig. 11 shows the comparing total cost for (IDD-HPO) in the personal computer against (IDD-HPO) in cloud environment based on fcs and bcs which can be calculated by Equations 8, 15 the total cost for (IDD-HPO) in fcs is less than the total cost for (IDD-HPO) in personal computer and total cost for (IDD-HPO) in bcs which satisfies the required conditions for the proposed method in case 2.

TABLE III. PERFORMANCE MATRIX FOR (IDD-HPO) BY USING FCS AND BCS

Classifier	Accuracy for (IDD-HPO)	Time delay for (IDD-HPO) (fcs)	Time delay for (IDD-HPO) (bcs)	Energy consumed for (IDD-HPO) (fcs)	Energy consumed for (IDD-HPO) (bcs)
LR	0.671	2	3	8	6
KNN	0.883	3	5	9	7
SVM	0.901	8	10	11	8
RNN	0.854	15	18	20	16
CNN	0.963	220	290	301	252

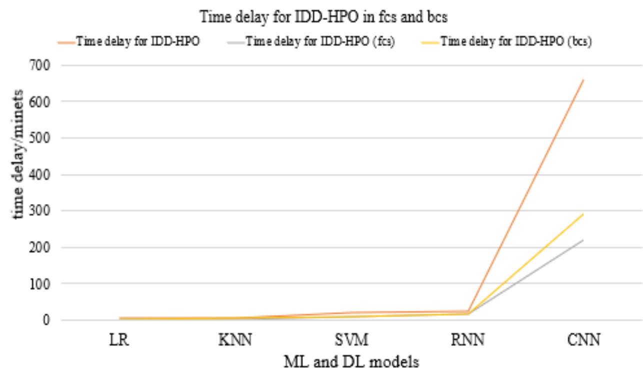


Fig. 9. Time Delay for (IDD-HPO) in Personal Computer and Cloud Server.

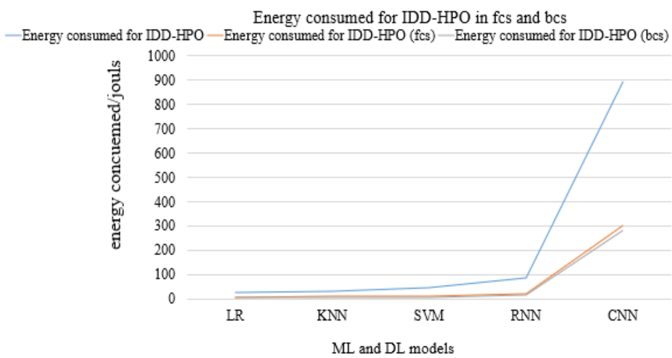


Fig. 10. Energy Consumed for (IDD-HPO) in Personal Computer and cloud Server.

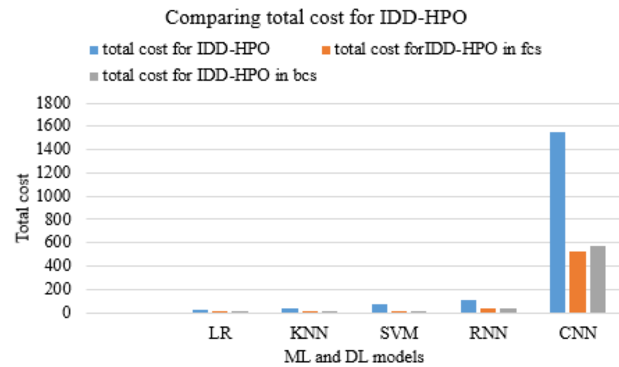


Fig. 11. Comparing Total Cost for (IDD-HPO) with a Personal Computer, FCS, and BCS.

C. Comparative Analysis against State-of-the-Art Models with our Results

In this section, a comparison between the proposed model with the highest accuracy measures ((IDD-HPO)) and other state-of-the-art models illustrated before in the related work section is discussed. Table IV provides a complete analysis of such a comparison. It compares (IDD-HPO) model with other models reported in [7], [11], [2], [8], [3], [4], and [6]. Each one of these models used different ML and DL algorithms with different preprocessing methods (e.g. [7] used ML and DL algorithms, [11] used Categorical Embeddings and Neural Networks, [2] used Data Mining technique with Random Forest, [8] used Multilayer Perceptron, [3] used Multilayer Perceptron (MLP) and Deep Neural Network, [4] used ML with Ensemble Technique, and [6] used CNN with Normalization technique).

TABLE IV. COMPARATIVE ANALYSIS AGAINST STATE-OF-THE-ART MODELS WITH OUR RESULTS

Year	**LR**	**KNN**	**SVM**	**Simple Neural Network**	**RNN**	**CNN**	**Computing environment**	**Model basis**	**Ref.**
	Readmission Prediction Accuracy								
Proposed model	**0.671%**	**0.883%**	**0.901%**	-	**0.854%**	**0.963%**	A personal computer system (anaconda3)	(IDD-HPO) model	-
(2021)	0.642%	0.872%	0.886%	0.873%	0.837%	0.924%	A personal computer system (anaconda3)	ML, RNN, and CNN with non-normalization Technique	[7]
(2021)	---------					0.952%	Personal computer system	Categorical Embeddings and Neural Networks	[11]
(2021)	0.898%						Personal computer system	data mining techniques with random forest	[2]
(2019)	---------					0.95%	Personal computer system	Multilayer Perceptron	[8]
(2019)	0.840%						Personal computer system	Multilayer Perceptron (MLP) and Deep Neural Network	[3]
(2019)	0.635%	-	0.2946%	0.7999%	-	-	Personal computer system	ML with Ensemble Technique	[4]
(2018)	---------					0.92%	Personal computer system	CNN with Normalization Technique	[6]

The proposed model (IDD-HPO) model used hyperparameter optimization which achieves high accuracy for ML algorithms as follows: LR=0.671%, KNN=0.883%, SVM=0.901%), and for reported high accuracy for DL algorithms as follow: RNN=0.854%, and CNN=0.963%. It also comes with the advantage of hyperparameter which is used to control the learning process and evaluates the problem to finding a set of optimal hyperparameters and return the best performance with the smallest time delay and energy consumed.

VI. Results and Discussion

In the first experiment, DL and ML performed higher when ((IDD-HPO)) was used in a personal computer compared to state-of-the-art models. DL algorithms especially CNN reported an overall accuracy of 0.963% using (IDD-HPO) model. But according to performance metrics, time delay and energy consumed for (IDD-HPO) model in DL (CNN) was very high, 660 minutes for time delay and 895 joules for energy consumed.

In the second experiment, (IDD-HPO) model was used for ML and DL algorithms in the MCC system to improve performance matrices by decreasing time delay and energy consumed, at the first data sets must be stored in the cloud according to how to map mobile data item taking intoaccount the limited resources of a mobile device by selecting the most suitable storage level for each data item to decreasing the time of training band testing for hyperparameter tuning. The result was that time delay and energy consumed for (IDD-HPO) model in a cloud environment for DL (CNN) was 220 minutes and 201 joules respectively if data store in the cloud as fcs and 290 minutes and 252 joules, respectively if data store in the cloud as bcs.

Based on these results, (IDD-HPO) model can be used to improve the prediction of hospital readmission in two cases (personal computer and cloud environment) with an accuracy of 0.963% with the smallest time delay and energy consumed if the process of training and testing will be done in a cloud environment based on storing data as fcs.

VII. Conclusion and Future Work

In this paper, the proposed model ((IDD-HPO)) using hyperparameter optimization with ML and DL to improve prediction of hospital readmission over a clinical data set, after applying some preprocessing on the input data then ((IDD-HPO)) is using with ML classifiers (e.g., LR, KNN, and SVM) and DL algorithms (e.g., CNN, RNN) to improve the performance of models. The performance of model was tested and evaluated under two different environments.

The proposed (IDD-HPO) model is successful to improve the accuracy of prediction of hospital readmission in a personal computer compared to state-of-the-art models. Then improve time delay and energy consumed by decreasing them if (IDD-HPO) model performed in cloud based on storing data at fcs. That will have a strong effect on the health care costs and the hospital's efficiency and reputation.

As future work, the (IDD-HPO) will be improved to not only be limited to numbers and text data but also to apply to dynamic audio and video data with the use of hybrid storage in the cloud according to the importance of the data used.

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Emotional Cascade Model and Deep Learning

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***Abstract*—Emotional Cascade Model proposes that the emotional and behavioral dysregulation of individuals with Borderline Personality Disorder can be understood through emotional cascades. Emotional cascades are vicious cycles of intense rumination and negative affect that may induce aversive emotional states that generate abnormal behaviors to reduce the effect of intense rumination. Borderline Personality Disorder is a psychiatric disorder whose main symptoms to diagnose it are mood instability and impulsivity. This disorder often involves risky behaviors such as non-suicidal self-injury or substance abuse. Recently, Selby and collaborators have proved that the Emotional Cascade Model has a high explanatory and diagnostic capacity using Temporal Bayesian Networks. Taking into consideration the meta-analytic study developed by Richman et al., in this article it has been designed a deep learning model, based on cascading artificial neural networks, following the correlations established for the Emotional Cascade Model. It has been confirmed with accuracy estimates reaching up to 99%, the predictive power of this model relative to the various types of rumination that influence some of the basic classes of symptoms of Borderline Personality Disorder.**

***Keywords*—Emotional cascade model; borderline personality disorder; rumination; deep learning; cascade-correlation algorithm**

I. Introduction

Borderline Personality Disorder (BPD) is a psychiatric disorder characterized by symptoms such as affect instability, impulsivity, self-harm and identity disturbances [1]. Such syndrome causes behaviors as suicidality [2], non-suicidal self- injury (NSSI) [3], chronic pain [4], substance abuse [5], binge-eating [6], and gender violence [7]. The pioneering and perhaps most complete theory of BPD has been that of Linehan [8]. It is a biological, psychological and social theory claiming that individuals with BPD develop extreme emotional vulnerability.

Selby, Anestis and Joiner [9] propose in their Emotional Cascade Model (ECM) that the cycle of affect and rumination (the emotional cascade) leads to dysregulated behavior that functions to distract attention from this negative internal experience. Rumination is typical in people with BPD and predicts dysregulated behavior [10]. It is a form of repetitive thinking in which individuals focus their attention on emotionally relevant stimuli [11,12]. Rumination usually magnifies negative affect. According to the ECM, the reciprocal relationship between negative affect and ruminative processes results in an "emotional cascade", which is initiated by an event that elicits an emotion. This event causes the individual to ruminate intensely, increasing the intensity of the emotion. As the intensity of the emotion increases it is more difficult to escape from the emotional experience paying full attention to the emotional stimulus. Then, it is generated a positive feedback loop between rumination and negative affect. There is a synergistic [13] effect between rumination and negative emotion predicting impulsive behaviors typical of BPD and forming emotional cascades [14]. Emotional cascades create a complex disorder that may be involved in the emergence of BPD. Emergence is the phenomenon by which a complex system arises from the interaction of its component network [15]. Broadly speaking, there is bidirectionality between emotional cascades and symptoms of BPD.

There are various types of rumination. The most common in BPD patients are pain rumination [16], depressive rumination [17,18] and anger rumination [19]. Anger rumination is repetitive thinking about anger experiences and has maladaptive outcomes such as physiological arousal or aggressive behavior. Stress and anxiety rumination can also appear [20,21]. Nolen-Hoeksema conceptualizes the depressive rumination as repetitively focusing on the fact that one is depressed and the possible causes and consequences of the depressive symptoms [22].

Richman et al. [23] have performed a meta-analysis to assess how the four main categories of BPD symptoms (affect-instability, relationship issues, self-harm/impulsivity, and identity disturbances) correlate with the five types of rumination mentioned above (pain rumination, depressive rumination, anger rumination, anxious and stress rumination). This meta-analysis of the correlations extracted between the data provided by 13 studies has supplied us with the basis for designing a cascading artificial neural network capable of simulating the ECM for BPD. Cascade-correlation (CasCor) [24] is an algorithm starting with a minimal network architecture, to which hidden nodes are added as required, forming feature detectors within the network. It is an algorithm especially suitable for modeling developmental cognitive cascades as Shultz does in [25] or processes such as representational redescription [26, 27]. The author of this article has also used it to model the psychological phenomenon of catastrophic worry [28] or the interaction between cytokines appearing together with lymphopenia in COVID-19 disease [29].

Deep learning uses multiple layers with non-linear processing units to extract and transform features. Each layer uses the output of the previous layer as input. Cascade-correlation algorithm is a pioneering algorithm in this type of machine learning, since it adds new layers as new neurons are added, in a constructive process that avoids the disadvantage of having to predeterminate the structure of an artificial neural network from the start [30] and adapts very adequately to the modeling of any cascade phenomena by means of “cascades” of layers.

In this article is demonstrated, using deep learning techniques, how it is possible to computationally model with an exceedingly small error the interaction between the network elements that intervene in the emotional cascades typical of patients with BPD. Thus, it has been reinforced the predictive value obtained by Selby and collaborators [31] about their model of emotional cascades of psychological disorders and it has been reaffirmed, using the technique of artificial neural networks, the value of their model as a source of explanation for these disorders. Using a different computational technique, it has been improved the accuracy in the validation of the model-reaching 99%.

II. Literature Review

Computational psychiatry [32] is a recent field that addresses a phenomenon as complex as mental illness using computational tools. We can distinguish between biophysical models (for instance, in [33] has been studied the role of dopamine in the central cortex of patients with schizophrenia), reinforcement learning models (for example, in [34] has been investigated the relation between reinforcement learning and the diagnosis of Alzheimer Disease), connectionist models (the first major paper on a neural network model of psychopathology [35] simulated the processing of the information on schizophrenia and in the 1990s came the first anthologies of articles [36,37]) and Bayesian network models.

Selby et al. [31] have proposed a Temporal Bayesian Network (TBN) model to examine the ECM in a sample of adolescents and young adults who actively self-injure and including those with BPD.

TBN is an extension of the Bayesian technique incorporating time dependence [38]. A TBN model consists of several connected clusters of nodes, one cluster corresponding to one-time step. The clusters of nodes at different time steps are interconnected in the same way within each cluster. The connections among the clusters of nodes correspond to the time dependence of the variables, updating one´s knowledge of other variables by calculating the posterior probability distribution over the remaining variables given the obtained evidence. Four core features of the ECM were modeled and used in model prediction evaluation: (a) rumination and negative emotion generate positive feedback on each other, (b) they generate positive feedback on themselves, (c) these positive feedbacks provoke dysregulated behavior, and (d) dysregulated behavior then reduces rumination and negative emotion. Time invariant variables for psychiatric diagnosis were specified. These variables were BPD, Major Depressive Disorder (MDD), and Posttraumatic Stress Disorder (PSD) and they were used in determining model predictive accuracy of BPD diagnosis, state rumination, negative emotion, and dysregulated behaviors. The predictive accuracy was then evaluated based on real-world data and using the *k*-fold cross-validation method [39] on interim models. Several interim models were initially built. For each of the models, a model structure was first generated using causally connected nodes corresponding to the momentary negative emotion, rumination, and dysregulated behavior, measured at five-time steps during each day, and including nodes corresponding to the diagnostic statuses of the participants. TBN analysis suggested that the ECM predicted BPD diagnosis (with accuracy estimates around 90%) and momentary prediction of rumination, negative emotion, and dysregulated behaviors with accuracy estimates above 80% and reaching up to 100%, depending on the level of momentary prediction selected.

III. Materials and Method

A. Database

The database used the correlations between BPD symptoms and types of rumination obtained by Richman et al. [23] selecting the results provided by 13 articles. Following to [23], when correlation values were not available, correlation values were calculated from reported univariate t-statistics, or p-values. Correlations were classified as small (0.1-0.3), medium (0.3-0.5), and large (0.5-1). To assess homogeneity of the correlation sizes across studies for each rumination domain, the Cochran Q-statistic was used. In all cases, significant at $p<.001$ and 95% CI. For N=28,165, Table I shows the types of rumination correlation with BPD symptoms that have been used as the parameters for adjusting the weights of the connections between the units of the neural network.

Besides, Table II shows the BPD symptoms correlation with rumination for the same sample. Also, these correlations have served for adjusting the weights of the artificial neural network.

TABLE I. Types of Rumination Correlation with BPD Symptoms

Types of rumination	***Overall BPD symptoms correlation***
Overall rumination	0.41
Pain rumination	0.68
Anger rumination	0.46
Depressive rumination	0.39
Stress rumination	0.35
Anxious rumination	0.28

TABLE II. BPD Symptoms Correlation with Rumination

BPD symptoms	***Overall rumination***
Overall symptoms	0.43
Affective instability	0.42
Unstable relationship	0.39
Identity disturbance	0.37
Self-harm/impulsivity	0.25

B. Design of the Artificial Neural Network

It has been used MemBrain (version V03.08.01.00) software, created by Jetter [40], for the design of the artificial neural network. Cascade-correlation algorithm seems adequate to simulate the ECM and, therefore, the positive feedback between types of rumination and the main BPD symptoms. BPD is an emerging phenomenon that allows explaining, through the spread of emotional cascades, why unregulated behaviors are succeeding each other. Subjects respond more and more negatively towards these behaviors and their cognitions are distorted in a process that Selby [41] calls “expectancy validation” and that adds more suffering to the subjects.

The cascade-correlation architecture is a multi-layer supervised connectionist learning system. The most interesting difference between it and other multilayer systems is that in a cascading artificial neural network the number of hidden units is not predetermined. Instead, these units are added as necessary and achieve a progressive reduction in error. The network starts with only specified inputs and outputs. Neurons are typically trained off-line, and a pool of new hidden neurons or candidates is created. The best of these candidates is situated in a separate layer and connected to the output neurons. If a candidate correlates positively with the error at a given neuron, it will develop a negative weight to compensate for that error, while if the correlation is negative, the weight will be positive. The weights on the connections to the new hidden neurons are frozen and the input-output and hidden-output connections are re-trained to readjust overall performance. This process is repeated until the total error at the output has converged or there has been a lack of significant improvement in error (stagnation) over a period of epochs (patience).

The learning algorithm has been cascade-correlation using backpropagation and target net error has been 0.01. The weights of the connections between the neurons have been initially randomized until adjusting to the values indicated in Table I and Table II. A symmetric logistic activation function has been used with values between -0.5 and 0.5 and an error threshold of 0.4. We have established as parameters, the learning rate (η), the maximum growth rate (μ) which limits the size of any change in weights performed after each presentation of the training set, the weight decay (γ) which ensures that the weights do not grow excessively, the patience percentage calculated from the change in error required over a period to continue training, the patience period or the period over which the change in error is measured through epochs (or lesson runs), and the activation function offset. When the maximum number of epochs has been reached or no progress has been made in the training of the candidate neurons, the best candidate is placed into the network and the output layer is retrained. The algorithm cycles through installing hidden nodes. In the following Table III, we indicate the values for output layer training parameters.

It has been designed the artificial neural network by introducing 11 units, of which the input neuron has been overall rumination (O-RUM), in a first layer, 5 neurons have been placed referring to the 5 types of rumination (P-RUM, A-RUM, D-RUM, S-RUM, AX-RUM, respectively) and the candidate neurons have been the units corresponding to the four main types of BPD symptoms (AI, UR, ID and SH), to end in the output O-BPD that corresponds to the overall BPD.

The maximum number of candidates has been 8 and the size of the set of candidates has been 4. For the training candidates, the correlation stable tolerance has been 5%.

The structure of the network can be seen in the Fig. 1 and the training parameters of the candidates can be seen in the Fig. 2.

TABLE III. OUTPUT LAYER TRAINING PARAMETERS

Parameter	***Output value***
η	0.4
μ	1.5
γ	0.0
Patience percentage	1%
Patience period	300
Activation function offset	0.1

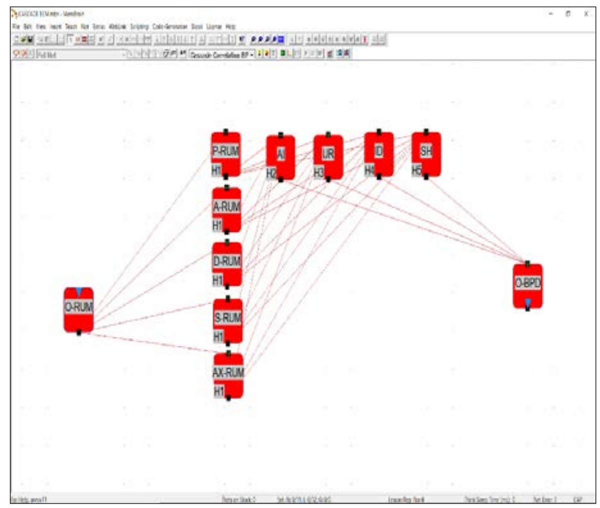

Fig. 1. Structure of the ANN (All the Neurons are Activated in Red and the Connections in Red Express Positive Weights).

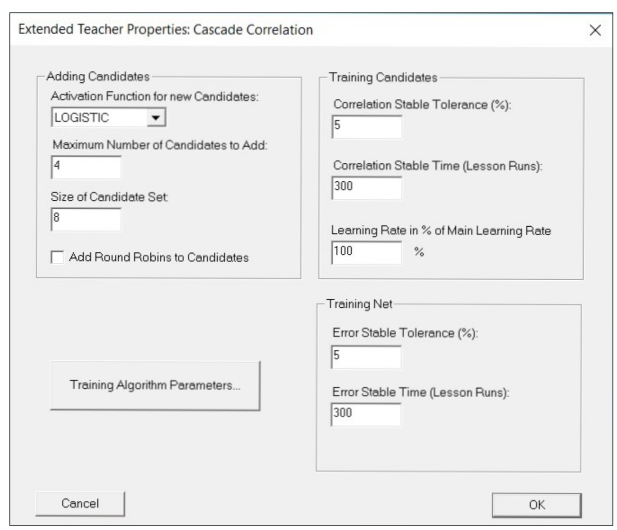

Fig. 2. Training Parameters of the Candidates in the Net.

IV. Result and Discussion

The learning rule has been applied to minimize the Mean Squared Error (MSE), which is calculated with the average difference between the observations and the expected values, obtaining the result with the iterations produced with the help of the learning algorithm. As Fig. 3 of the Net Error Graph shows, the Net Error has been 0.00991199644037891.

This result proves that the correlations established by the meta-analytic study [23] between types of rumination and overall rumination and the main classes of BPD symptoms and overall BPD allow designing a computational simulation using an artificial neural network in cascade that adjusts in a remarkably high degree to these correlations. By the way, it has been improved the precision in the validation of the ECM by means of a different computational technique. Selby and colleagues used a Temporal Bayesian Network and, in this article, has been employed a cascading neural network. Using this computational tool, it has been reached a validation of the ECM of almost 100%.

The fundamental merit of the ECM is to capture very well the inherently dynamic and cascading nature of the BPD as it is fed by rumination and the negative affect generated. In other perspectives, BPD is understood as a hardwired disorder activated by emotions. In the ECM, the BPD symptoms are increased by an intense rumination process that, in turn, generates negative emotional states. BPD unfolds over time periods far beyond the presence of the emotions that caused the symptoms, and the component processes themselves (called “hysteresis”), a nonlinearity that is typical for complex systems. The symptoms are maintained and affect the emotional state space influenced by rumination and negative emotions. Of course, not all rumination processes are identical, but BPD cascade is amplified by a persistent rumination process.

BPD psychopathological preconditions and effects are accurately simulated by the computational architecture of a cascading artificial neural network, as we have tried to demonstrate in this article.

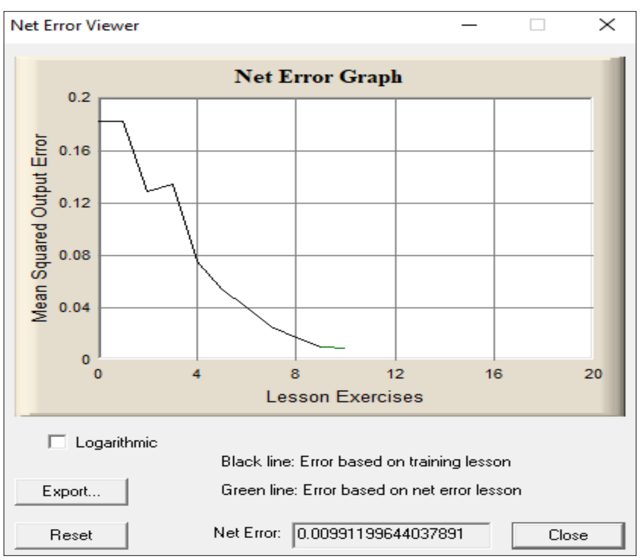

Fig. 3. Net Error.

Really, the cascade-correlation algorithm is suitable for modeling numerous psychopathological processes that present a cascade structure, that is, processes that take place in a staggered fashion and that start a cycle with positive feedback. For instance, disorders such as neurosis or catastrophic pain deserve to be computationally modeled using this kind of artificial neural network. Furthermore, psychological processes involving developmental cascades, that is, processes by which function at one level of behavior affect the organization of competency in later developing domains, admit to being modeled following this methodology and not simply the usual models of structural equations that do not capture the constructive and evolutionary nature of this class of systems.

V. Conclusion

This article has sought to design a suitable artificial neural network (ANN) for simulating the Emotional Cascade Model (ECM) by Selby and collaborators applied to the borderline personality disorder (BPD). According to ECM, the main BPD symptoms are triggered by an insidious rumination process that generates negative emotional states. These negative emotional states, in turn, intensify the rumination types and the borderline symptoms. The ANN type has been a cascade-correlation network with backpropagation. Cascade-correlation architecture is well suited for modeling cascading events. These events are self-amplifying cascades of strong negative emotions. Cascading networks with backpropagation grow in a similar manner to the process of emotional cycles typical of the ECM and have allowed us to validate the correlations between the main symptoms of BPD.

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Diabetes Classification using an Expert Neuro-fuzzy Feature Extraction Model

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***Abstract*—Diabetes is one of the challenging diseases prevailing in recent times. Due to the incompleteness, uncertainty and imprecise details, classification of diabetes using machine learning algorithms is turning out to be even more challenging. The efficiency of the classification model is influenced by the data present in the dataset. This study enhances the classification of diabetes by using a Neuro-Fuzzy model with special attention to Feature Extraction. The main goal of the present study is to enhance the diabetes prediction technique that helps the medical practitioners to easily identify the disease and diagnose it appropriately to reduce several complications that diabetes may cause to the patient in the future. The proposed model initially applies fuzzification on diabetes data to produce membership values. Later the membership values are examined by the proposed model to check the contribution of the features in diabetes classification. The feature extraction algorithm passes the significant features to a neural network after the features are extracted. The proposed model is tested on standard PIMA diabetic dataset to evaluate the performance. The proposed model is able to outperform all the existing machine learning algorithms.**

***Keywords*—Diabetes; neuro-fuzzy model; feature extraction; artificial neural network**

I. Introduction

Diabetes is now one of the most affecting diseases on the human race. Diabetes occurs mainly due to the insufficient production of insulin in the body. As per the details of the World Health Organization (WHO), diabetes is rapidly increasing in developing and underdeveloped countries. It is expected that by 2030, the severity of the disease increases very drastically, becoming a dreadful disease that will lead to the death of many human beings [1], [2]. Diabetes comes in three variations; namely Type I, Type II and Gestational.

Type I diabetes occurs mostly in children and is very rare, Gestational diabetes occurs during pregnancy, but both of these are very rare. Type II diabetes is more common in humans [3]. Type II diabetes causes a serious effect on the health of an individual and at present, there is a lot of research going to predict diabetes at the early stages using various models [4], [5]. Type II diabetes models require appropriate algorithms to efficiently detect the disease and thus help physicians to diagnose the disease early [6]. Early diagnosis [7] of the disease helps to overcome the impact that diabetes causes on various organs in the human body like kidneys, heart, eyes, etc. The disease prediction models that handle the diabetes data often face issues like noisy, missing, irrelevant and inconsistent data [15], [16].

The performance of the model depends on the quality of the diabetes data presented to the model and hence the researcher must supplement accurate data to the classifier for effective disease prediction [17]. In the machine learning domain, classification is an important task as it derives knowledge to handle real-world applications [18], [19].

Classification constructs a model to predict the target class of the data accurately. Classification models like artificial neural networks (ANN) do not work efficiently to produce high accuracy due to their slow convergence rate, also suffer from the local minima problem and is a very high computational model. Although ANN is adaptive, it requires a high amount of time to produce the result because of its complex structure. ANN is not ideal to deal unclear, imprecise details [7].

To address the various issues of ANN, this paper aims to develop an ANN-based fuzzy model (ANNFM) that converts the numeric features into appropriate linguistic terms such as very low (VL), low (L), medium (M), high (H), and very high (VH). Each feature in the dataset is converted into a suitable membership value based on the five linguistic terms mentioned above. Thus all the features in the dataset are converted into linguistic features. Fuzzy logic enhances the ANN model to deal with the uncertainty problem by giving membership values to all the features. The proposed model performs classification by using fuzzy logic and the ANN model. The majority of classification models reduce the features at the pre-processing stage. This leads to loss of information and prediction capability will be affected if the features are reduced in the training process. Hence the proposed approach considers all the features initially and applies fuzzification on the features to determine the significant features for efficient decision making. The main motive of this research is to develop a model that integrates the linguistic terms of fuzzy logic and ANN and to use an efficient feature extraction algorithm to classify the data.

The rest of the paper is organized as follows: the second section covers the existing work in this domain. Section 3 presents the proposed approach for diabetes classification based on fuzzy linguistic terms and artificial neural networks with special attention to feature extraction. Section 4 presents the results of the proposed approach and the state-of-art

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diabetes classification approaches. Section 5 concludes the paper with a direction towards possible future aspects.

II. Related Work

This section covers the related work in the domain of diabetes classification and management. This section also explains how the existing models predicted different alignments using neuro-fuzzy models.

This work [7] presents an adaptation of neuro-fuzzy inferences to perform the classification of electrocardiogram signals. This model integrated the benefits of fuzzy inference system with the neural network for better classification of electrocardiogram signals. This work [8] presents a machine learning paradigm to classify diabetic data. The work focused on applying classification techniques like linear discriminant analysis, Naive Bayes to classify the PIMA dataset. The authors did not focus on efficient preprocessing techniques. The performance of various classifiers using various evaluation metrics is reported in this paper. But due to inefficient handling of missing data the results are not higher on the PIMA dataset.

The authors in [9] performed the classification of diabetes using the Levenberg-Marquardt learning algorithm. The authors constructed a neural network to perform the classification of the PIMA diabetes dataset. The algorithm is dynamically applied to the neural network to calculate the sensitivity and specificity of the developed model. The authors did not handle the missing values of the dataset properly and hence the results of this model are not promising.

The work [10] presents a model to classify diabetic data. This model aims to integrate Ant Colony-based optimization model with fuzzy rules to diagnosis the diabetic data. The optimization proved effective in classifying the data and achieved better results. This work [11] presented an ensemble system to diagnose diabetes using J48 and Adaboost techniques. The main work this paper focused on is to use the rules to help undiagnosed individuals to reduce the risk of diabetes incidence. The main aim of this work is to classify different adult groups of Canada and help the physicians to carry out the research. The works [12], [14] are also a machine learning approach to predict diabetes on the PIMA dataset.

The authors [13] proposed a neural network-based model using radial basis function to classify the diabetes data. The model comprises hidden layers also to increase the performance of the classification. The model uses the Bat-based clustering approach to find the number of neurons required in the hidden layer. The works [19], [20] focused on diagnosing kidney disease in the patients who are affected with the diabetes using classification. The authors [21] worked on the adverse effects that diabetes disease cause with respect to cardiovascular and kidney diseases.

Few models based on deep learning [15], [16] also stressed the importance of analyzing the diabetes at the early stages. All the discussed models in this section focused on diabetes classification only. The machine learning algorithms also paid attention to classify diabetes data. The discussed models paid little attention to the data pre-processing and fuzzification aspects. Hence in the next section, an efficient model to perform data preprocessing efficiently and to apply the fuzzy linguistic parameters to enhance the artificial neural networks for classifying type-II diabetes on the PIMA dataset is presented.

III. Materials and Methods

This section provides the detailed description of the proposed work and the dataset used.

A. *Assigning Fuzzy Membership Values to the Features in the Dataset using Fuzzification and Performing Classification of Data*

The initial phase is to perform the fuzzification process on the data. Each entry in the dataset consists of many features. In the first phase, this work converts the feature into a linguistic term like VL, L, M, H and VH.

If dataset is having ‘P’ records with each ‘n’ features per record,

$$P_i = [\, f_{i1}, f_{i2}, ...f_{in}] \tag{1}$$

Where ‘i’ represents the ith record in the dataset and f_{ij} represents the jth feature of the record.

For each feature in the record membership values are assigned using the π-type function. The π-type assigns fuzzified values based on the five linguistic terms. Hence, the feature vector contains 5*n fuzzified features, if there are ‘n’ features per record.

$$f_{ij} = [\mu_{VL}(f_{ij}), \mu_{L}(f_{ij}), \mu_{M}(f_{ij}), \mu_{H}(f_{ij}), \mu_{VH}(f_{ij})] \tag{2}$$

The data is transformed into fuzzy membership values initially. Once each feature is assigned with five membership values, the size of the feature vector grows significantly which increases complexity. To overcome this problem, the present work uses principal component analysis to store all the significant features and discard the unnecessary features. Moreover, the data in the dataset has many missing values. This paper uses imputation techniques to fill the missing data and after the fuzzification process, all the significant features are restored. The procedure of the proposed methodology is shown in Fig. 1. There are two phases in the proposed approach. Fig. 1 shows the detailed step by step working principle of the paper.

The first phase performs two tasks, a) fuzzification of data and b) feature extraction. The second phase handles the neural network aspects of the model. After the feature extraction model, a suitable neural network is built to perform classification of data. The process of classification is shown in Fig. 2. The input to the ANN is membership values of the feature vector. The initial weights of the network are in the range (0, 1). The input layer has as many nodes equivalent to the number of features after feature reduction. The output layer has nodes equivalent to the number of the classes in the dataset.

B. *PIMA Dataset*

This dataset has records of 768 patients and for each record there are 8 features and a class label, specifying whether the patient is diabetic or non-diabetic. The description of various attributes of the dataset is mentioned in Table I.

The dataset has many missing values. The proposed model has used imputation techniques to fill the missing values in the dataset. For example, the Glucose column in the dataset has 374 and the skin thickness column has 227 missing values. Along with these two columns, there are some other missing values in the dataset also. This work applies the imputation technique to fill the missing values. Later the features in the dataset are assigned fuzzy membership values and after this, the significant features are extracted using principal component analysis. The feature vectors of all the records of the PIMA dataset are obtained at this point.

The missing values in the dataset are shown in Fig. 3. From the figure, it is observed that the skin thickness and insulin are having more missing values.

In this paper imputation techniques are used to fill the missing values of the dataset for efficient classification. After the imputation, the correlation of the attributes in the dataset is shown in Fig. 4.

From Fig. 4, it is observed that the attributes pregnancies and age are more correlated. BMI and skin thickness, Glucose levels and Insulin are also more correlated.

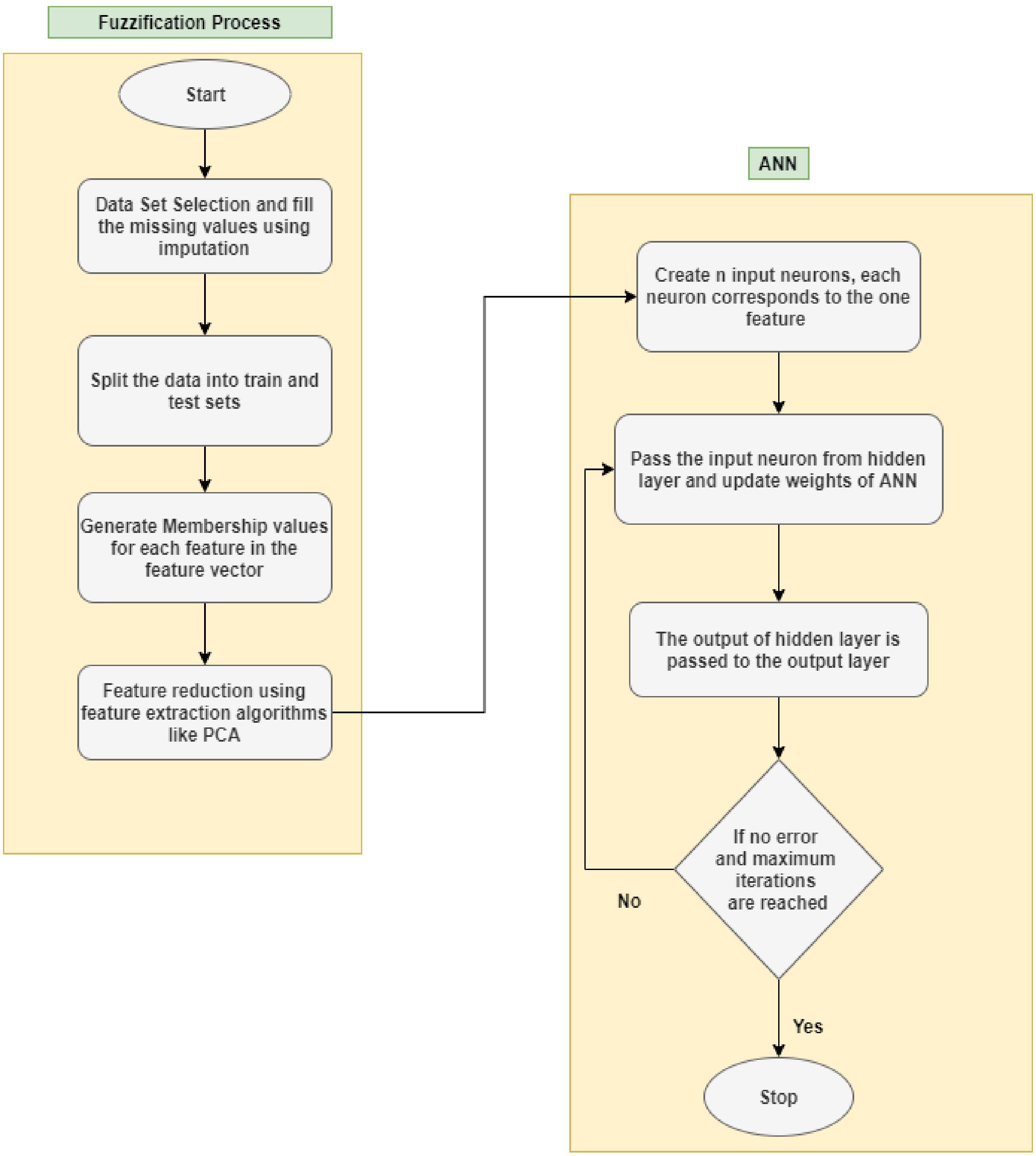

Fig. 1. Architecture of Proposed Model to Classify Diabetes.

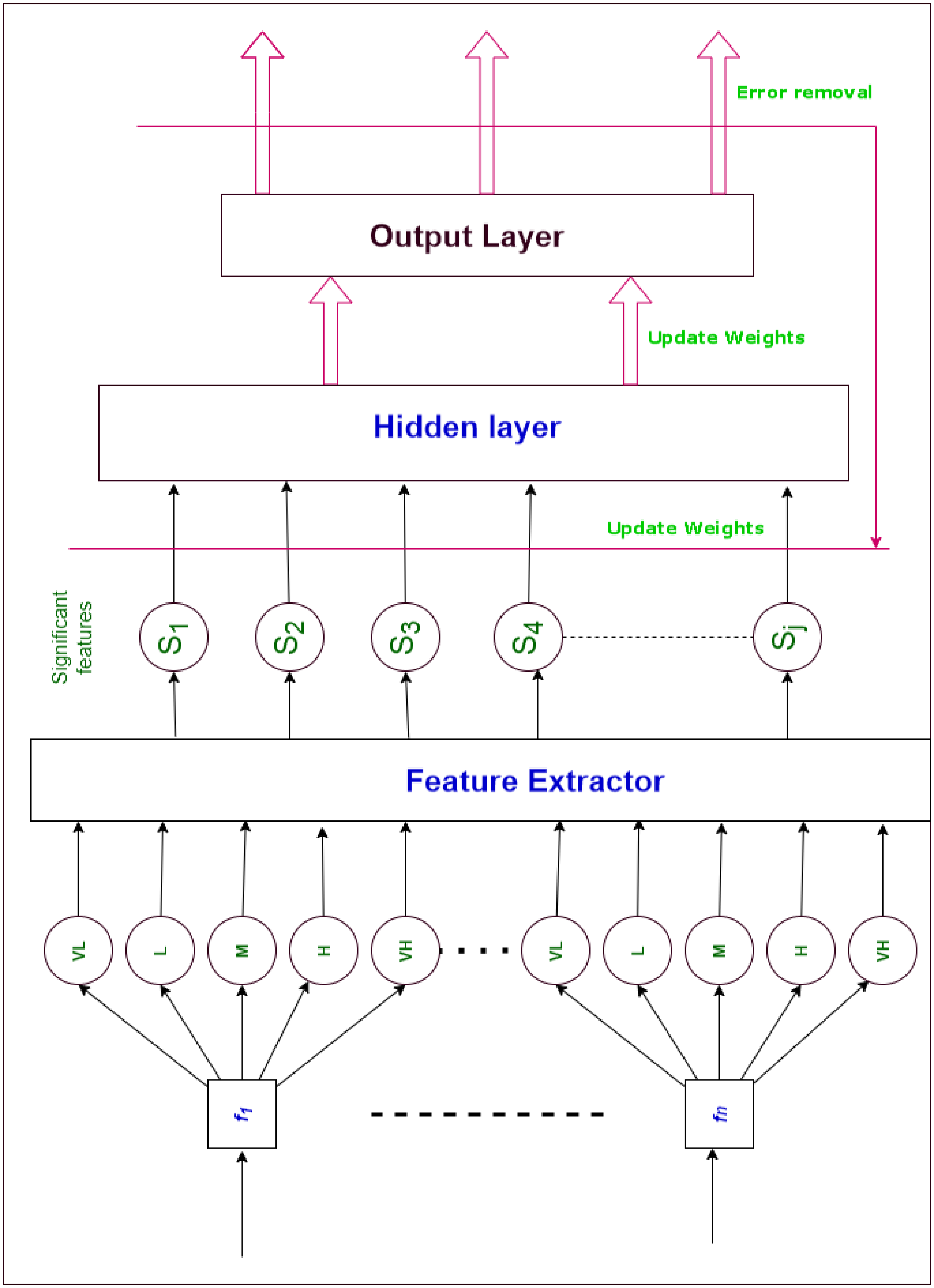

Fig. 2. Neural Network with Fuzzy Feature Vector with Various Membership Values.

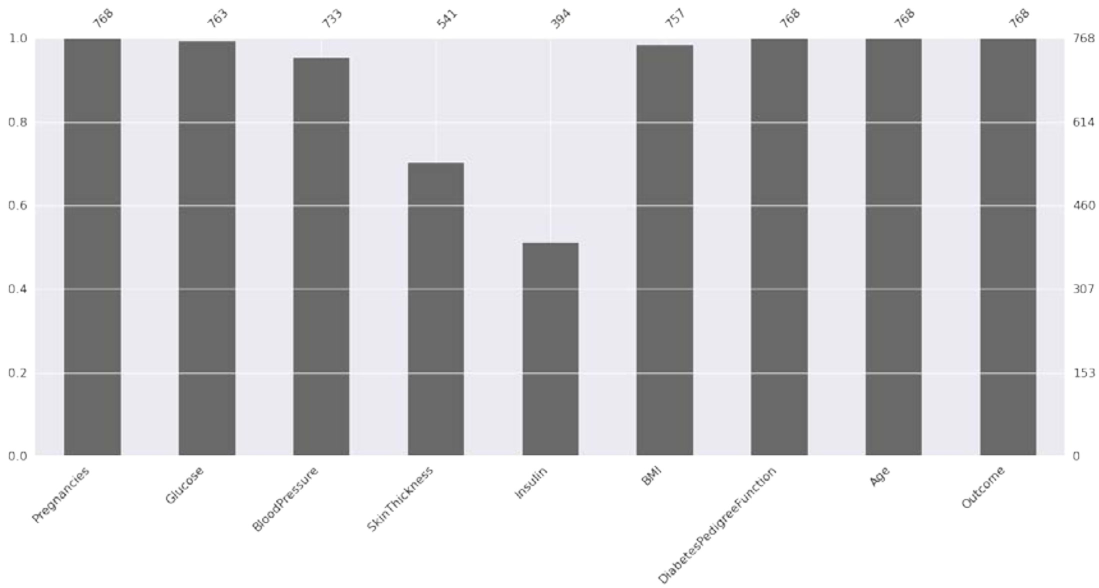

Fig. 3. PIMA Dataset.

TABLE I. PIMA DATASET DESCRIPTION

Attribute	Attribute Description
P	Count of number of times pregnant
G	The concentration of Plasma glucose concentration
BP	Blood pressure
ST	It gives the thickness of skin folds.
I	Two-hour serum insulin.
BMI	Body Mass Index
PF	Relatives history regarding diabetes
A	Persons age
O	Class of diabetes (Yes- 1, No -0)

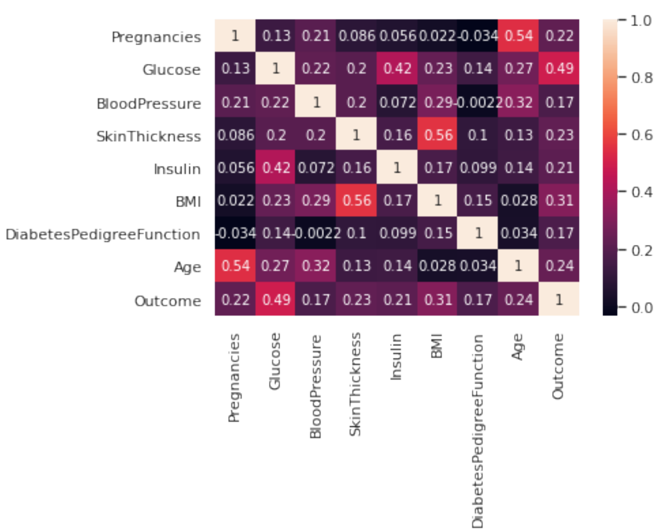

Fig. 4. Correlation of Attributes after Imputation.

Fig. 5 and 6 show the attribute values for a diabetes and non-diabetes patient. Fig. 5 shows the attributes of the PIMA dataset. The figure contains all the attribute values of the Diabetes patient.

Fig. 6 shows the attributes of a non-diabetic patient in the PIMA dataset. From both the figures it can be observed that there is a clear distinction in the ranges of the values of most of the attributes.

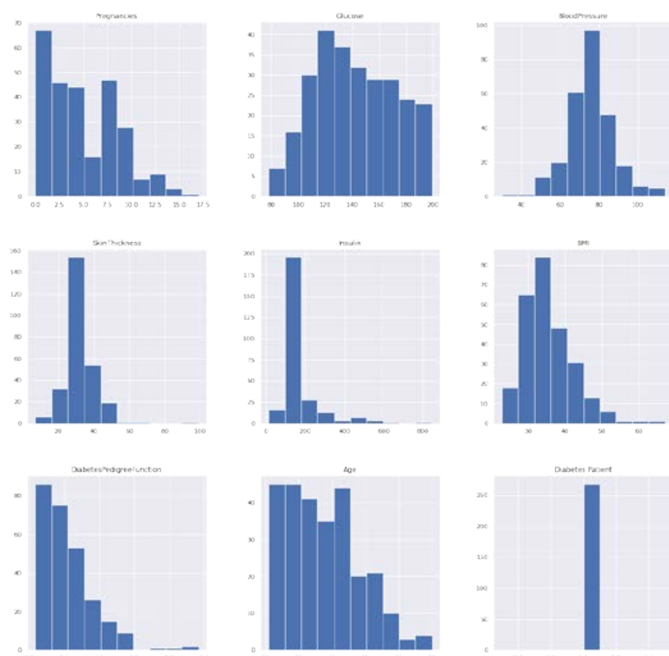

Fig. 5. Attributes for a Diabetic Patient in PIMA Dataset after Imputation.

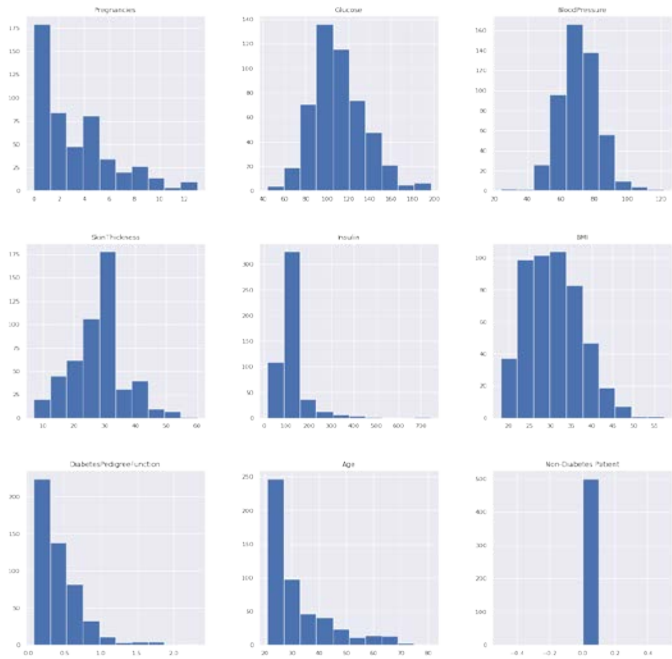

Fig. 6. Ranges of the Attributes for a non-Diabetic Patient in PIMA Dataset after Imputation.

To classify the dataset, the dataset is split into 70-30 ratio for training and testing purposes. The feature vector is the input to the neural network. The input layer assigns weights initially and passes this to the hidden layer and performs the classification task. The weights are updated until the network reaches a certain threshold. The next section provides the results of the proposed approach.

IV. Results and Discussion

In this section, the experimentation and results of the proposed approach on the PIMA dataset are given. Machine learning approaches like Decision trees, J48, SVM, Logistic regression are used for comparison.

The following are the evaluation parameters used in this paper to evaluate the performance of different models:

$$Accuracy = \frac{Number of correct predictions}{Total predictions} \quad (3)$$

$$precision = \frac{tr\_pos}{tr\_pos + fl\_pos} \quad (4)$$

$$recall = \frac{tr\_pos}{tr\_pos + fal\_neg} \quad (5)$$

$$F1 = 2 * \frac{pr * re}{pr + re} \quad (6)$$

Table II shows the results of various approaches on the PIMA dataset. From the results, it is observed that the proposed approach outperformed all the existing machine learning algorithms.

TABLE II. Comparison of different Algorithms with the Proposed Algorithm Enhanced Naïve Bayes Classifier on PID Dataset

Model	Accuracy	Precision	Recall	F1-score
Decision tree	73.16	0.73	0.73	0.70
SVM	71.85	0.71	0.72	0.68
J48	73.16	0.73	0.73	0.70
Logistic Regression	70.80	0.68	0.69	0.65
Naïve Bayes	76.92	0.77	0.77	0.77
ANN	82.00	0.81	0.81	0.80
ANN with fuzzy rules	82.33	0.85	0.83	0.81
Proposed Approach	**84.66**	**0.87**	**0.86**	**0.82**

Machine learning models like Decision tree and SVM achieved 73.16, 71.85 accuracy levels. J48 and Logistic regression model achieved 73.16 and 70.80 accuracy. Compared to these machine learning models Naïve Bayes achieved highest results. But the performance of neural networks on PIMA dataset is relatively high. The neural network model integrated with fuzzy rules also outperformed the other machine learning model results. But the highest accuracy level 84.66 is obtained when PIMA dataset is tested with the proposed model. The proposed model is able to outperform the existing models because of the following reasons:

1) The proposed model introduced fuzzy membership values for each feature in the input feature vector.

2) The significant features of the model are retained using principal component analysis.

3) The model is trained with artificial neural network and the weights are updated till there is minimal error.

The proposed work compared to other models has more advantages as the model is based on neuro fuzzy model. The model can be easily enhanced to predict the other diseases at early stages. The proposed model has outperformed all the machine learning algorithms. It is easy to draw the inferences using fuzzy models to predict the diseases and also the fuzzy model enables to easily classify the data compared to the other models.

V. Conclusion

Diabetes is considered a very serious disease in recent times since it causes many health complications. Hence, the researchers are trying to bridge the gap between technology and the medical field by developing various methods to ease the treatment procedures. In this regard, this work proposed a neural network model using fuzzy linguistic terms to classify diabetes data. The proposed model used linguistic terms to assign membership values to the features of the data and performed feature extraction using principal component analysis. After feature reduction, the features are passed to the input layer of the artificial neural network and the weights of the neural network in the input and hidden layers are updated until the error minimizes. The main goal of the proposed research is to predict the disease at early stages to deal with the other complications that may arise in the future. The proposed model aims to develop a robust approach for the early detection of diseases to mitigate the adversaries that the disease may cause to the patient and to help the practitioners in medical domain to diagnose the diabetic patients. Moreover, the proposed model is able to outperform all the existing machine learning approaches.

In future, the research can be easily extended to predict and diagnose other diseases. The proposed work can be modified with fuzzy inference rules to improve the performance. The present study can deal with the missing data of smaller datasets and in future it can be enhanced to handle large amounts of data.

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A Multiagent and Machine Learning based Hybrid NIDS for Known and Unknown Cyber-attacks

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***Abstract*—The objective of this paper is to propose a hybrid Network Intrusion Detection System (NIDS) for the detection of cyber-attacks that may target modern computer networks. Indeed, in the era of technological evolution that the world is currently experiencing, hackers are constantly inventing new attack mechanisms that can bypass traditional security systems. Thus, NIDS are now an essential security brick to be deployed in corporate networks to detect known and zero-day attacks. In this research work, we propose a hybrid NIDS model based on the use of both a signature-based NIDS and an anomaly detection NIDS. The proposed system is based on agent technology, SNORT signature-based NIDS, machine learning techniques and the CICIDS2017 dataset is used for training and evaluation purposes. Thus, the CICIDS2017 dataset has undergone several pre-processing actions, namely, dataset cleaning, and dataset balancing as well as reducing the number of attributes (from 79 to 33 attributes). In addition, a set of machine learning algorithms are used, such as decision tree, random forest, Naive Bayes and multilayer perceptron, and are evaluated using some metrics, such as recall, precision, F-measure and accuracy. The detection methods used give very satisfactory results in terms of modeling benign network traffic and the accuracy reaches 99.9% for some algorithms.**

Keywords—Intrusion detection; zero-day attacks; machine learning; multi-agent systems; security

I. Introduction

The Global Internet Usage Statistics report confirms a growth of 1,114% and more than 2 quintillion bytes of data are generated every day. Along with this growth, cybercrime is becoming more sophisticated and continues to grow day by day [1, 2, 3]. As a result, the risks of being attacked and targeted by the hacker community remain more likely and could be costly for victims of cyber-attacks. Thus, the importance of Network Intrusion Detection Systems (NIDS) continues to grow and attract the interest of researchers [4] and NIDSs have become indispensable for securing network infrastructures against cyber-attacks [5]. However, the evolution of NIDSs is slowed down due to several challenges that are mainly related to the volume of network data, the emergence of increasingly sophisticated attacks [6] and unbalanced learning datasets [42]. In addition, real-time processing of network traffic is a very important feature of an effective NIDS to monitor all network events [8]. Not to mention that network traffic is continuously changing and therefore, the training datasets need to be updated regularly to effectively evaluate the detection models [5]. According to [22] and [42], the lack of more adequate datasets for anomaly detection-based intrusion detection has caused intrusion detection methods to suffer in analysis and deployment. The authors of [7] confirm that all these challenges remain a blocking obstacle against the evolution of the IDS domain in terms of performance, accuracy, and execution time during the learning and detection phases. Furthermore, the approaches proposed in the literature are not clear in terms of architecture and do not opt for hybrid architectures adopting, both, signature-based and anomaly detection-based NIDS. Most of the research works, carried out in this sense, remain theoretical and do not propose more efficient mechanisms capable of detecting known and unknown attacks.

In this research work, we will propose an effective intrusion detection approach to detect known and unknown cyber-attacks. Our approach consists of a Snort-based intrusion detection model to detect known intrusions and then machine learning techniques to detect any suspicious deviation from the baseline profile of benign network traffic. This baseline is designed by regularly training the system on normal network events using machine learning methods.

The selection of the research works carried out by the scientific community working on cybersecurity was done using a database of 17 journals (Q1 and Q2) and the used search terms are presented in Fig. 1 according to the methodology of [44].

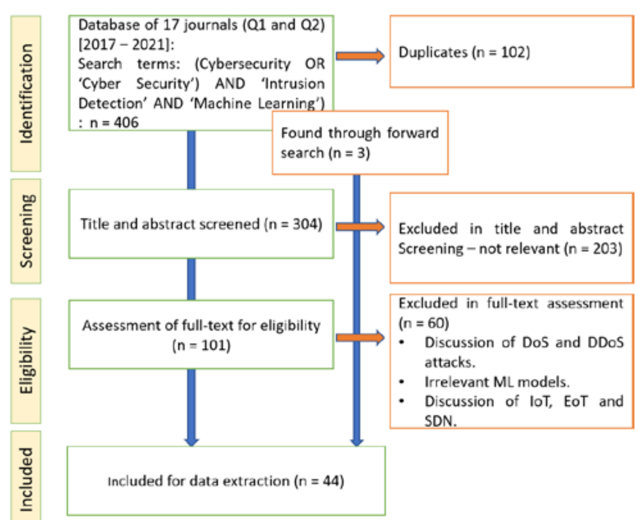

Fig. 1. Flow Diagram to Perform Papers Selection.

The remainder of this paper is structured as follows. Section II highlights some related works conducted by scientific community. Section III highlights gives some basics related to our theme of research. Section IV presents our proposed approach and finally Section V handles the conducted tests and experiments to validate the classification of benign network traffic.

II. Related Work and Discussion

A. Related Work

In this section, we will highlight some of the research works that have been carried out by researchers to ensure a quick advance of intrusion detection mechanisms based mainly on Machine Learning, Data Mining and Deep Learning techniques.

Since the beginning, researchers started to propose various approaches to effectively deal with the problem of Intrusion Detection. Notably, the Table I below summarizes some of the research works carried out by the scientific community to contribute in enhancing NIDS.

B. Discussion

It is true that several research works have been conducted by researchers to develop the field of intrusion detection systems. However, most of the aforementioned works have shortcomings in terms of architecture, datasets used as well as the machine learning methods used and each research work addresses a specific problem. For example, in the paper [25], the researcher limited himself to intrusion detection in wireless networks, in [39], the author proposed an IDS for SDN-based networks etc. In our research work, we will propose a universal NIDS, capable of being deployed in any type of computer networks. Our NIDS model will be based on a multi-layer architecture with the use of the multi-agent paradigm and will also be based on a hybrid detection mechanism combining a Signature-based NIDS (SNIDS) and an Anomaly-based NIDS (ADNIDS).

TABLE I. Research Works Carried Out in the Intrusion Detection Field

Ref	Approaches	Techniques
[23]	Intrusion detection system based on feature selection and ensemble classifier.	+ CFS-BA heuristic algorithm to reduce dimension of the training dataset + Combination of C4.5 and Forest by Penalizing Attributes to classify data
[24]	Method of intrusion detection	+ Auto-Encoder deep learning agorithm and Random Forest to reduce the dimension of the dataset
[25]	Intrusion Detection System for wireless networks	Feed-Forward Deep Neural Network and Wrapper-based Feature Extraction Unit techniques using UNSW-B15 and AWID datasets.
[26]	Model of a real-time IDS that can distinguish between benign and malicious network traffic.	+ Support Vector Machine (SVM) and Extreme Learning Machine to detect known and unknown attacks + Modified K-Means to get a good quality and small training dataset from KDDCUP
[27]	Attribute selection method	Pigeon Inspired Optimizer algorithm
[28]	New application of Deep Reinforcement Learning for intrusion detection.	+ Deep Reinforcement Learning to detect intrusions + NSL-KDD and AWID datasets
[29]	An intrusion detection mechanism to model benign traffic	Supervised machine learning methods to model benign network traffic
[30]	Comparative study of Snort and Suricata.	Plugin which is based on the SVM and Fuzzy Logic algorithms to reduce the False Positive rate.
[31]	Cooperative IDS	+ Machine Learning methods + Proactive decision making based on previous exchanges + Denoising Autoencoder and DNN
[13]	Intrusion detection architecture to detect attacks targeting the Cloud networks.	Machine Learning methods
[32]	An IDS for wireless networks	Deep Gated Recurrent Unit and Wrapper-based feature extraction using NSL-KDD
[33]	Hybrid model to detect intrusions using Deep Learning	Convolutional Neural Network and Weight-Dropped, Long Short-Term Memory network.
[34]	A comparative study between the different approaches of intrusion detection.	Describing of 35 known datasets used in the field of Intrusion Detection
[35]	A new intrusion detection technique	+ Semantic Re-encoding and Deep Learning + NSL-KDD dataset
[36]	Collaborative intrusion detection system for Internet of Things (IoT) networks.	+ Semi-supervised machine learning algorithms + Tests conducted on real IoT environments.
[37]	An approach for intrusion detection in Edge-of-Things.	Deep Belief Network (DBN)
[38]	A model of adaptive intrusion detection system to detect known and unknown cyber-attacks.	Extreme Learning Machine
[3]	State of the art study of IDSs based on public datasets.	More visibility into what is being done by the scientific community to identify unknown cyber-attacks and to better understand the problems that such IDS suffer from.
[4]	State-of-the-art study of various previous cybersecurity surveys focused on Deep Learning.	Details about IDS including input data, detection mechanisms, deployment modes as well as different evaluation strategies.
[39]	An approach for intrusion detection in Software Defined Network (SDN).	Decision Tree algorithm.
[40]	Hybrid IDS	Signature-based detection and Anomaly-based detection.

Our NIDS model will be based on mutli-agent technology in order to make the system modular and distributed. Thus, the proposed system will be extensible and capable of adding other components to perform large-scale detection missions in huge networks. Moreover, as we have already said, our system combines both detection mechanisms (SNIDS and ADNIDS) in order to detect all types of attacks (known and unknown). The used SNIDS is based on the famous open source NIDS SNORT and allows the detection of known intrusions. Moreover, ADNIDS intervenes when the packet is not recognized by the SNIDS and compares the packet's characteristics against the baseline patterns (benign traffic) modelled by supervised machine learning techniques applied to the cleaned and optimized CICIDS2017 dataset.

In order to improve the accuracy and precision of the used detection mechanism to model the benign network traffic, we opted for cleaning and reducing the dimension of the CICIDS2017 dataset. Thus, the used training dataset is devoid of any unnecessary information that could falsify the classification results.

III. Context of the Study

A. Cybersecurity

Cybersecurity is a discipline that has been evolving exponentially over the past decade [9]. It refers to the set of practices to protect the cyberspace environment against suspicious activities that may affect its security principles [10]. Among the security principles, we have the integrity of the data that aims to prevent the alteration of the information by unauthorized persons. The second principle is confidentiality, which confirms that the data should not be accessible by malicious people and finally the principle of high availability which ensures that the computer assets are available at any time to serve legitimate requests [11, 12].

B. Intrusion Detection Systems

The Intrusion Detection System (IDS) is one of the key components for ensuring the security of mobile clouds [13]. IDSs are classified according to the data source and the used detection method. Based on the nature of data sources, we can distinguish between two types of IDS: Host-based IDS and Network-based IDS. Furthermore, based on the used analysis method, we have two types of IDS: Signature-based IDS and Anomaly-based IDS [2].

NIDS analyses network traffic passing through computer environments [14, 3]. Its role is mainly to monitor the network events against suspicious activities that may violate or bypass security policies of security components such as firewalls, Web Application Firewalls and proxies. A NIDS usually consists of three main modules which are Monitoring, Analysis and detection, and Alarm modules. The Monitoring module observes network traffic, resource usage and patterns. The Analysis and Detection module is the key part of the system; it identifies cyber-attacks based on specific algorithms. Finally, the Alarm module is responsible for notifying the security administrators in case of possible intrusions [15]. Furthermore, conventional security mechanisms cannot detect unknown zero-day attacks [16] that have no signature or whose patterns are not yet known to security experts. Another issue that modern computer networks are facing is that network traffic is responding to Big Data issues (volume, variety and velocity). As a result, network traffic processing must make use of Big Data technologies to improve the quality of analysis and to reduce execution time during learning phases [17].

C. Snort: Open source Network Intrusion Detection

Snort is an open source IDS developed by Sourcefire in 1998 and has gained a very good reputation over the past decade due to its frequent use by researchers. Snort is structured in a TCP/IP stack architecture to capture and inspect network packets. This IDS is in its version 3.0 just released to overcome the single-thread limitation to support by default multithreading [18].

D. CICIDS2017 Dataset

A dataset for intrusion detection is developed by collecting network traffic events from heterogeneous sources. These events can describe system, user and configuration behaviors [19]. These datasets do not include network events that can represent zero-day attacks [20]. The CICIDS2017 dataset is one of the most modern datasets [21].

IV. Proposed Approach

A. Proposed Model

1) Architecture of the proposed model: Fig. 2 presents the proposed intrusion detection system model to ensure the detection of known and unknown attacks (0 Day) within any type of computer network. The proposed architecture is mainly based on three layers that collaborate together to perform cyber-attack detection missions.

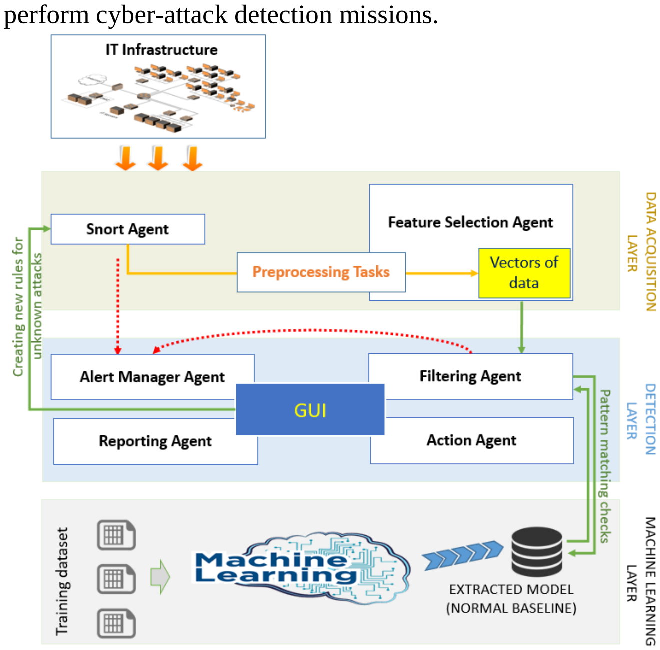

Fig. 2. The Proposed Network Intrusion Detection System.

2) Components of the proposed model

The system has three main layers:

- Data Acquisition Layer (DAL): This layer is responsible for data capture and pre-processing of network traffic. It also performs feature extraction to transform the captured network packets into data vectors to be used by machine learning methods. The DAL includes Snort Agent, a small component responsible for pre-processing tasks and an agent responsible for feature extraction.
- Detection Layer (DL): This component is responsible for detecting deviations from a network baseline. It is based on a machine learning model developed after training the system on a training dataset containing benign network traffic. The DL also sends alerts when an intrusion is detected and allows the security administrator to generate reports and take actions on the network and system infrastructure in case of a security incident.
- Machine Learning Layer: This part allows the NIDS system to perform training tasks on normal network behavior. Using supervised machine learning techniques on a dataset including benign network traffic, a model is developed that will check the fit to detect deviations from the designed baseline.

B. *Operating Principle*

Our system must be trained regularly on benign network traffic devoid of any type of cyber-attacks. Thus, datasets like CICIDS2017 are used to develop and design a baseline identifying the normal operation of a computer network. The training process of the proposed NIDS is mainly done in six steps:

- Data acquisition: The system collects data to train itself and to obtain the network baseline describing normal network behaviors. We used the CICIDS2017 dataset (Benign traffic) devoid of any kind of cyber-attacks.
- Pre-processing: In order for the data to be exploitable by machine learning based classification techniques, data preprocessing actions must be undertaken. Thus, missing value removal, scaling and partitioning techniques are all used to improve the quality of the training dataset.
- Classification: In this step, machine leaning based classification techniques are used to model the normal behavior of the network based on the benign dataset. Several machine learning algorithms are used to select the one with the highest accuracy, with very low false alarm rates and with an increased processing speed.
- Testing and validation: After using a set of machine learning techniques, it is now time to evaluate these algorithms based on specific metrics that address intrusion detection issues. From there, the most efficient machine learning technique is chosen to model the normal network traffic.
- Use of the model “Baseline”: After modeling the baseline of the network during normal operation based on the CICIDS2017 dataset, the generated model will be used to identify any deviation from normal behavior. Thus, unknown 0day attacks can be easily identified.

C. *Real Time Detection Flowchart*

Fig. 3 shows the detection principle of our NIDS model. Indeed, our system is supposed to train beforehand on benign network traffic that does not include any trace of cyber-attack, so the generated model will be considered as the network baseline to which the system will compare the real network packets.

Our system ensures the detection of intrusions in the networks according to the following steps:

- Step 1 – Sniffing and gathering: During this step, the NIDS listens to the network to collect all the packets that are passing through it. To do this, the proposed model relies on the Snort agent to capture the network traffic.
- Step 2 – Matching check: During this step, the Snort agent compares the patterns of the network packets it receives against a signature database describing all known cyber-attacks (Snort DB). Based on the result of the matching check, the Snort agent notifies the NIDS administrator if there is a known attack in the network.
- Step 3 – Data preprocessing: At this point, the captured packet is not recognized by Snort's knowledge base. Therefore, the network traffic must undergo pre-processing operations so that it can be consumed by machine learning algorithms. Thus, feature extraction techniques are applied to the captured network traffic in order to transform the data streams into data vectors that can be exploited by machine learning models.

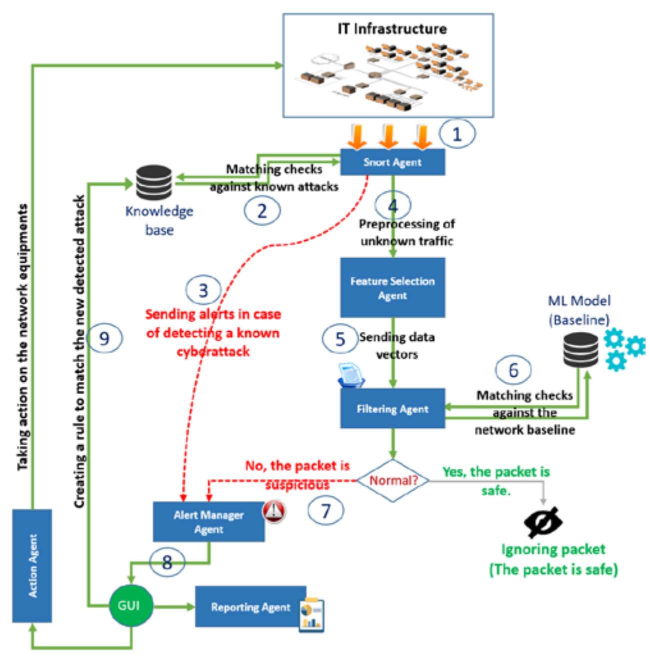

Fig. 3. The Flowchart of the Detection Mechanism.

- Step 4 – Filtering and matching check: After transforming the network flows into data vectors, the Filtering Agent checks the match between the data it receives and the "Network Baseline" model previously generated after training the system on benign network traffic. Depending on the result of the matching verification, two scenarios could arise: If the network packet is normal, no alert is generated and if the packet does not match the network baseline, the NIDS administrator must be informed in time to analyse the event.

- Step 5 – Enrichment of the Snort knowledge base: In case an event deviates from the network baseline, the NIDS system must notify the administrator. The administrator must then intervene to diagnose and analyse the suspicious event, and can also contact security vendors and publishers to identify the nature of the suspicious network event. The security administrator can create rules in the Snort to intercept similar events that may occur in the future. The detected suspicious network event can be Zero-day attacks for which the security vendors have not yet developed a patch or signature.

V. Experimentation and Tests

This section focuses on the experiments and tests performed to evaluate the performance of the different algorithms used for benign traffic modeling. For this purpose, the CICIDS2017 dataset is used and therefore it is necessary to analyze and clean it before using it by machine learning algorithms.

A. *Composition of the used Dataset*

We analyzed the CICIDS2017 dataset published by the Canadian Cybersecurity Institute using the Pandas framework in Python. The latter allowed us to analyze the content of the various CSV files constituting CICIDS2017 dedicated to research in the field of intrusion detection systems based on Machine Learning and Deep Learning.

The CICIDS2017 dataset consists of a set of eight files in a CSV format; these files include data about network traffic captured during five days from Monday to Friday. After analyzing the content of the set of CSV files using Pandas, we were able to identify the composition of the CICIDS2017 dataset and Table II summarizes the obtained results.

From the above statistics, it appears that the dataset is unbalanced due to the abundance of normal traffic compared to attack traffic, in addition to the existence of few records of certain types of attacks. This imbalance in the traffic classes automatically implies a biased machine learning model. Knowing that the class with a lot of traffic will be favored over the others with less records during the learning stage. As a result, the classes with few records make the machine learning model learn nothing about them and consequently have a biased detection model towards attacks with few records in the learning dataset.

TABLE II. Composition of the CICIDS2017 Dataset [41]

Day	Class of captured traffic	Number of records
Monday	Benign	529918
Tuesday	Benign	432074
	SSH-Patator	5897
	FTP-Patator	7938
Wednesday	Benign	440031
	DoS Hulk	231073
	DoS GoldenEye	10293
	DoS Slowloris	5796
	DoS Slowhttptest	5499
	Heartbleed	11
Thursday Morning	Benign	168186
	Web Attack Brute Force	1507
	Web Attack Sql Injection	21
	Web Attack XSS	652
Thursday – Afternoon	Benign	288566
	Infiltration	36
Friday – Morning	Benign	189067
	Bot	1966
Friday – Afternoon – PortScan	Benign	127537
	Port Scan	158930
Friday – Afternoon – DDoS	Benign	97718
	DDoS	128027

B. *Cleaning and Pre-processing of the Training Dataset*

As we already said, the CICIDS2017 dataset dedicated to researchers operating in the field of intrusion detection is composed of eight files. Hence, these files need to be merged into one more comprehensive, one including all the labelled network traffic. The concat() function in Pandas was used to concatenate the set of CSV files and then the to_csv() command could then be used to export the concatenated dataset in CSV format. Fig. 4 shows the workflow adopted to clean, balance and reduce the size of the CICIDS2017 dataset.

C. *Experimenting with Machine Learning Techniques to Model benign Traffic*

In this part, we will see some machine learning algorithms that we applied on the optimized training dataset CICIDS2017. This experimentation consists in trying a set of algorithms that we will compare between them in order to retain only those effective and efficient that allow us to better modeling a network baseline during its normal operation (benign traffic). Throughout this phase, the Knime tool is used to evaluate the performance of the machine learning algorithms applied on the optimized dataset.

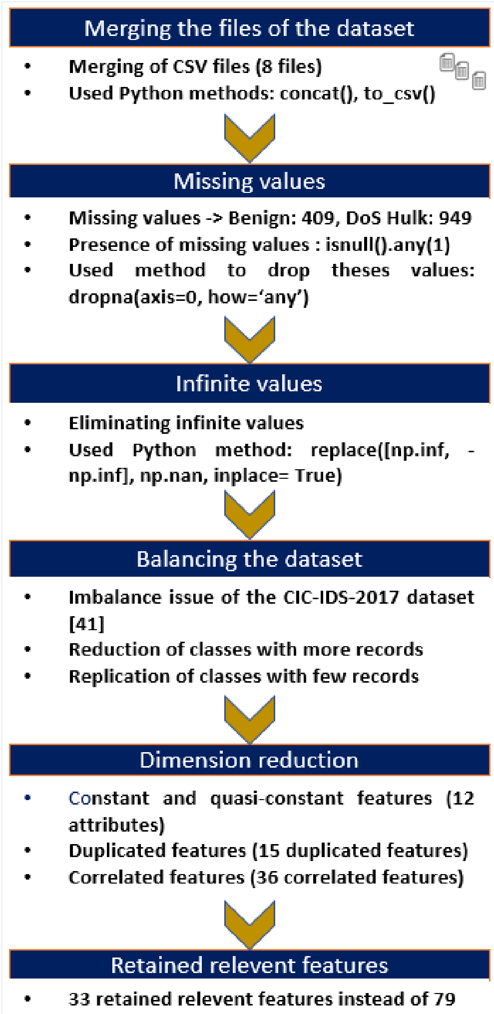

Fig. 4. The Performed Pre-processing and Feature Reduction Tasks to Optimize the CICIDS2017 Dataset.

1) Machine Learning algorithms used to model benign network traffic

a) Decision Tree: The Decision Tree (DT) algorithm was used and performed very well in terms of accuracy, false alarm rates, and execution time. According to the confusion matrix, it turns out that the Decision Tree algorithm provided better detection of all classes of network traffic. The accuracy reached 99.9% while classifying bengin network traffic. The Table III shows the confusion matrix and the Table IV summarizes the obtained results after applying DT algorithm on the optimized CICIDS2017 dataset.

The obtained results are conclusive and highlight the efficiency of the DT algorithm. We are interested in the accuracy of the algorithm with respect to the recognition of benign traffic, especially since our intrusion detection system relies on a baseline of the network during its normal operation. Thus, the Decision Tree was able to detect benign traffic with an accuracy of 99.99% and this, with a total number of false alarms equal to 229 (135 False Negatives (FN) and 94 False Positives (FP)).

TABLE III. CONFUSION MATRIX OF DECISION TREE TO CLASSIFY BENIGN TRAFFIC

Predicted	Actual		
		Positive	Negative
	Positive	74704	94
	Negative	135	174779

TABLE IV. PERFORMANCE STATISTICS OF DECISION TREE ALGORITHM TO CLASSIFY BENIGN TRAFFIC

Metrics	Rate (%)
Recall	99.8
Precision	99.9
F-Measure	99.8
Accuracy	99.9

b) Random Forest: The Random Forest is used to make the NIDS learn the normal behavior of the network. This algorithm performed very well in classifying the different classes of network traffic. As can be seen in Table VI, the detection accuracy reaches 99.8% for benign traffic using Random Forest classifier. RF is very effective in identifying benign traffic and thus designing the network baseline during its normal operation, knowing that the number of false alarms does not exceed 353 (FP: 75 and FN: 278) and with a number of TP equal to 74561 (see Table V).

c) Naïve Bayes: The Naive Bayes (NB) was also tested and unfortunately gave poor detection results for most classes of the dataset. For example, the correct detection of benign traffic is almost zero (accuracy reaches 100% for misclassified instances). Tables VII and VIII below show the statistics related to the use of NB algorithm. The classification of benign traffic is very low compared to other algorithms, as the accuracy does not exceed 70%.

TABLE V. CONFUSION MATRIX OF RANDOM FOREST TO CLASSIFY BENIGN TRAFFIC

Predicted	Actual		
		Positive	Negative
	Positive	74561	75
	Negative	278	174798

TABLE VI. EVaLUATION METRICS OF THE RANDOM FOREST ALGORITHM

Metrics	Rate (%)
Recall	99.6
Precision	99.9
F-Measure	99.8
Accuracy	99.8

TABLE VII. CONFUSION MATRIX OF NAIVE BAYES TO CLASSIFY BENIGN TRAFFIC

Predicted	Actual		
		Positive	Negative
	Positive	16	0
	Negative	74823	174873

TABLE VIII. EVALUATION METRICS OF THE NAIVE BAYES ALGORITHM TO CLASSIFY BENIGN TRAFFIC

Metrics	Rate (%)
Recall	0
Precision	100
F-Measure	0
Accuracy	70

d) MultiLayer Perceptron: Using the MultiLayer Perceptron (MLP) technique, the benign traffic was classified with an accuracy of 97%. Tables IX and X highlight the confusion matrix and the statistics obtained after using MLP-based technique.

TABLE IX. CONFUSION MATRIX OF MLP TO CLASSIFY BENIGN TRAFFIC

	Actual		
Predicted		Positive	Negative
	Positive	72227	4957
	Negative	2925	169603

TABLE X. EVALUATION METRICS OF MLP ALGORITHM TO CLASSIFIY BENIGN TRAFFIC

Metrics	Rate (%)
Recall	96.1
Precision	93.6
F-Measure	94.8
Accuracy	96.8

D. Summary of benign Traffic Classification Results

This section summarizes the obtained results after applying the classification algorithms on the optimized CICIDS2017 dataset. We emphasize that we are interested in modeling the network baseline in the absence of any suspicious activity. As a result, the different algorithms used at training time are evaluated based on the classification ability of benign traffic. Thus, Table XI summarizes the results obtained after applying the set of learning algorithms we saw in the previous section.

TABLE XI. SUMMARY OF THE OBTAINED RESULTS USING DIFFERENT MACHINE LEARNING ALGORITHMS

Algorithms	*Recall*	*Precision*	*Accuracy*
Decision Tree	***0.998***	***0.999***	***0.999***
Random Forest	***0.996***	***0.999***	***0.998***
Naïve Bayes	***0***	***1***	***0.7***
Multilayer Perceptron	***0.961***	***0.936***	***0.97***

From the summary table above, it appears that most of the techniques were able to model normal traffic. However, Naive Bayes did not perform well in classifying benign traffic. In addition, the Decision Tree and Random Forest are very efficient in terms of accuracy during training. However, the time complexity of the used algorithms is unfortunately not given in this work and will be the subject of our next article. For example, according to [43], the Decision Tree has a time complexity that is equal to O (mn2) where n is the number of instances and m represents the number of attributes. The temporal complexity metric allows for better evaluation of machine learning methods.

VI. CONCLUSION

It is true that many approaches based on machine learning techniques have been proposed to develop more effective and efficient NIDS. However, existing intrusion detection systems are still not able to detect unknown cyber-attacks more effectively. In this research work, we proposed a new approach based on a Multi-agent model, a Snort IDS and on machine learning techniques. The proposed NIDS is capable of handling network traffic that meets the big data issues in terms of volume and transition speed. First, we analysed the CICIDS2017 dataset with the aim of gaining more visibility on its composition, cleaned it up and removed unnecessary attributes. Then, we tried a set of classifiers on the optimized dataset in order to choose the most efficient algorithm in terms of detection and execution time. Thus, the Decision Tree and Random Forest algorithms give a detection accuracy of more than 99.8% for the detection of benign traffic. However, the work does not end here and the following tasks remain to be accomplished in a future work:

- Definition of how to create rules at Snort when a deviation from the baseline is detected,
- Using the benign traffic model to recognize normal packets in a production environment,
- Using a redundant and powerful module for processing and storing network traffic,
- Testing and validating the NIDS in a real environment.

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Software Quality Analysis for Halodoc Application using ISO 25010:2011

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Abstract*—The rapid spread of the Covid-19 disease and the ongoing social distancing have disrupted community activities. This consequently makes people use information and communication technology, especially in the fields of health, education, and business. The use of information and communication technology in the health sector plays an important role in preventing the spread of the Covid-19 disease. One of its uses is Telemedicine. One of the developing telemedicine in Indonesia is Halodoc. This study will test the quality of the Halodoc application to determine the quality of the Halodoc application using the model of the International Organization for Standardization (ISO), namely ISO 25010:2011. Software quality assurance can use this model as the basis for testing. Therefore the test will include 8 characteristics and 29 sub-characteristics. The assessment in this tests will use a weight where this weight is determined using Analytical Hierarchy Process (AHP) method. The testing method is carried out using Black-Box testing, stress testing, and distributing questionnaires to 100 respondents for Usability testing. Functional Suitability, Compatibility, Reliability, and Maintainability got a maximum score of 5. Performance Efficiency get a score of 4,886, Usability gets a score of 4, Security gets a score of 3,549, Portability gets a score of 3,718. The total results of the Halodoc application assessment get a score of 4,515 out of a maximum score of 5.

***Keywords*—Halodoc; ISO 25010:2011; software quality assurance; telemedicine**

I. Introduction

In 2020, the disease Covid-19 made the world difficult. The spread of this disease is so fast that the governments of each country are implementing isolation and social distancing. Indonesia is one of them. The Indonesian government has implemented social distancing to reduce the spread of the Covid-19 disease. The rapid spread of disease and social distancing rules that are still in effect disrupt community activities. Activities such as teaching and learning, working, doing business, and others cannot be carried out as usual. This effect makes people use information and communication technology, especially in the fields of health, education, and business [1]. The use of information and communication technology in the health sector plays an important role in preventing the spread of the Covid-19 disease. One of its uses is Telemedicine. Telemedicine is the service of remote health care services by all health care professionals using information and communication technologies. Another benefit of telemedicine is that it can prevent the spread of Covid-19 in Indonesia.[2]. One of the developing telemedicine in Indonesia is Halodoc.

Halodoc provides features that make it easier to consult with doctors, including about the Covid-19 disease that many people suffer from. This feature provides convenience because patients can consult a doctor anytime and anywhere, doctors available for consultation are available from general practitioners to specialists, patients can ask doctors about their disease and symptoms, and will be given treatment prescriptions according to the patient's illness. Perceived usefulness, perceived behavioral control, trust, self-health awareness, system quality, and attitude are factors that influence users in using Halodoc [3]. Therefore if the Halodoc application wants to make users satisfied using the application, it must pay attention to these factors. The quality of the system or software factor can be assessed by testing the quality of the software. The quality of the system or software can be assessed by testing the quality of the software so that users remain satisfied.

There are various methods or models of software quality testing. McCall model, Boehm model, or model of the International Organization for Standardization (ISO) like 9126-1 and 25010:2011 model, and many other models. The ISO 25010:2011 model includes all the quality factors of the previous model like the McCall model, Boehm model, and 9126-1 model [4]. Therefore, this model can be used as a basis for testing software quality.

This journal will use the ISO 25010:2011 model as the basis for testing the quality of the Halodoc application. Furthermore, the test will use eight characteristics of the model. The total assessment of the quality of the Halodoc application will be calculated using the weight determined in the research using the Analytical Hierarchy Process (AHP) method multiplied by the score from each characteristic. In addition, this journal will also use all sub-characteristics except Modularity and Modifiability of the Maintainability characteristic in the test. The supporting software that will be used in this research is “TestProject.io” which is used for Time Behavior testing, “UI/Application Exerciser Monkey” for Maturity testing, “Apache JMeter” for Availability testing, and “SPSS” for testing Validity and Reliability of the questionnaire.

This journal will organize as follows. First, this journal will provide a brief overview of related work. After that, this journal will explain the research methods that will be used. Next, it will present the research result and discuss it. Finally, this journal will give a conclusion about this journal.

II. Related Research Work

Previous research related to the topic of analyzing the quality of mobile applications already exists. First, there is a journal that uses the ISO 9126-1 model to measure electronic driving license application quality. The tool used for testing is a questionnaire, and the results from the journal are that the application meets the standard model 9126-1[5]. Nevertheless, this model is an old model. There is already a new model that develops from this model that is ISO 25010:2011 model [6].

Another research conducted a software quality analysis using the McCall model [7]. This model uses three characteristics, namely Product Revision, Product Transition, and Product Operation. This study aims to measure the quality of the financial system for cashiers. The results show that the performance of the system can still be improved. But the drawback of McCall's model is that the functionality of the application does not consider the functionality of the software [4].

Testing of quality analysis research uses the characteristics of the ISO 25010:2011 model. Those characteristics are Compatibility and Performance Efficiency. The test results from this study say that the Elektronika Analog application has a satisfactory quality. This research conducts the test using software cloud.bitbar.com. The test in this study has a weakness in which the Co-existence sub-characteristics are not tested [8].

Another research uses the ISO 25010:2011 model to ensure the quality of school information management applications. The test will use the characteristics like Functional Suitability, Usability, Performance Efficiency, Portability. Tests are carried out using tools such as gtmetrix for Performance Efficiency characteristics, System Usability Scale (SUS) for Usability characteristics, and Black-Box testing for Functional testing [9].

Other research uses the AHP method in calculating the final results of the test. The model used for testing is ISO 25010:2011. This research uses the characteristics like Functional Suitability, Reliability, Usability, and Performance Efficiency. The test method uses a questionnaire for all characteristics. The final result is calculated from the questionnaire data, which is then entered into the AHP. After that, the weights of the characteristics are compared to see which characteristics and sub-characteristics need improvement [10].

The difference between this journal and previous research is that it will use eight characteristics and all of their sub-characteristics except Modularity and Modifiability. Testing will also be carried out by determining the weight of each characteristic and sub-characteristic. The weight will be deterimined using AHP method. This weight is then multiplied by the value of each test performed.

III. Research Methods

A. Software Quality Assurance

A set of activities that define and assess the adequacy of the software process to provide evidence that establishes confidence that the software process is appropriate and produces a software product of the appropriate quality for the intended process [11]. Software Quality Assurance (SQA) software is a fundamental activity for many businesses that produce products that will be used by both internal and external users of the company. Software assurance has several purposes such as ensure that the team has carefully reviewed the requirements model for high quality, The design model must be assessed by the software team to ensure the high-quality model and meets the requirements, source code and associated work products must conform to local coding standards and exhibit characteristics that will facilitate software maintenance, SQA analyzes the allocation of resources for review and testing to assess whether or not resources are allocated in the most effective manner [12].

B. Characteristics and Sub-characteristics of ISO 25010 Quality Model

This ISO 25010 quality model consists of eight characteristics that are related to the dynamic and static properties of a computer system. The characteristics and sub-characteristics provide a consistent term for defining, measuring, and evaluating the quality of systems and software [13]. Fig. 1 shows ISO 25010:2011 diagram.

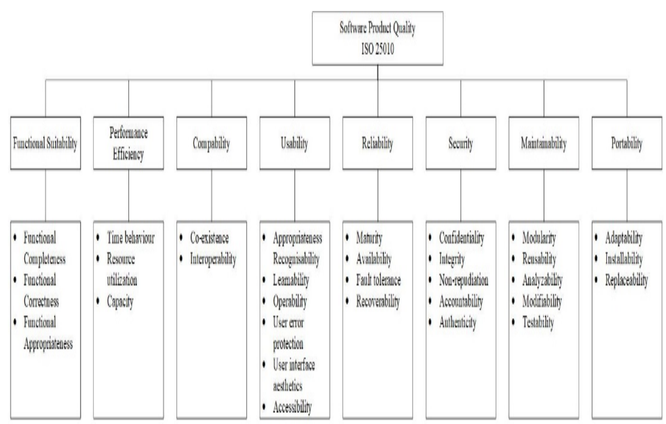

Fig. 1. ISO 25010:2011 Model.

Eight characteristics of ISO 25010 is Functional Suitability which represents the extent to which a product or system provides a function that satisfies stated needs when used under certain conditions. This characteristic has three sub-characteristics, namely: Functional Completeness, Functional Correctness, and Functional Appropriateness [14]. Performance Efficiency represents performance relative to the resources used under the stated conditions. This characteristic consists of sub-characteristics, namely: Time Behavior, Resource Utilization, Capacity [14]. Compatibility represents the extent of the system or product can exchange information or perform required functions with other system or product while sharing the same environment. This characteristic consists of sub-characteristics, namely: Co-existence and

Interoperability [14]. Usability represents if a system or product can be used by certain users to achieve certain goals with effectiveness, efficiency, and satisfaction in a particular context of use. This characteristic consists of sub-characteristics, namely: Appropriateness Recognizability, Learnability, Operability, User Error Protection, User Interface Aesthetics, and Accessibility [14]. Reliability represents how well a system, product or component performs a particular function under certain conditions for a certain period of time. This characteristic consists of sub-characteristics, namely: Maturity, Availability, Fault Tolerance, and Recoverability [14]. Security is the characteristic to know the extent a system or product protects information and data with a level data access following type and level of authorization. This characteristic consists of sub-characteristics, namely: Confidentiality, Integrity, Non-repudiation, Accountability, and Authenticity [14]. Maintainability is used to know the level of effectiveness and efficiency with which a product or system can be modified to improve it, improve it or adapt it to changing environments, and requirements. This characteristic consists of sub-characteristics, namely: Modularity, Reusability, Analyzability, Modifiability, and Testability. In this research, the sub-characteristic that will be used only 3, namely: Reusability, Analyzability, and Testability [14]. Portability will be used to determine the degree of effectiveness and efficiency with which a system or product can be transferred from one hardware, software, or other operational or usage environment to another. This characteristic consists of sub-characteristics, namely: Adaptability, Installability, and Replaceability [14].

C. Black-box Testing

Black-Box Testing is testing based on requirements specification and there is no need to check the code in Black-Box testing. This is purely done from a user point of view, only the tester knows the predictable set of inputs and outputs [15].

Black-Box testing plays an important role in software testing; it helps in validating the overall functionality of the system. Black-Box testing is done based on customer requirements-so incomplete or unpredictable requirements can be easily identified and can be addressed later [16]. The main advantages of Black-Box testing are required relatively few resources compared to White-Box testing, resource effectiveness can be done by testing automatically hence contributing to a shorter testing period, and ability to perform almost all test case groups, such as availability (response time) reliability, load durability and test groups related to the operation, revision and transition factors [17].

D. Stress Testing

Stress testing is used to test the reliability and stability of the system. This test can determine the system's resilience and fault handling under very heavy load conditions. Tests outside the normal operating point and evaluating how the system performs under these extreme conditions are included in Stress testing. Stress Testing is carried out to ensure that the system will not crash under crisis situations. The existence of large amounts of data with very high frequency and volume will result in the performance of the software being disrupted or not [18].

E. Questionnaire

A questionnaire is a data collection instrument used to collect large amounts of data. The trick is to provide several written questions in a structured manner to respondents related to their responses to the various variables studied [19]. Questionnaires can also be referred to as written interviews because the contents of the questionnaire are a series of written questions addressed to the respondent and filled out by the respondent himself. Things that need to be considered in compiling questions in the questionnaire use words that are easy to understand, questions that are not too general, avoid suggestive questions, avoid questions that embarrass the respondent, avoid questions that rely on the respondent's memory [20]. Usability testing will be conducted using the J.R. Lewis Usability questionnaire. This questionnaire uses a Likert scale. The data that will be obtained must pass validity and reliability test [21] (see Appendix).

The measuring instrument must perform a validity test and then test its reliability so that the measuring instrument is reliable with a reliability test. The validity test is used to determine whether the questions in the research instrument are valid or can collect information according to the questions given, while the reliability test is carried out to see the level of reliability of the research instrument. Especially research that is a case study, collects research data using research instruments [22].

F. Analytical Hierarchy Process

The Analytic Hierarchy Process (AHP) was introduced by Thomas L. Saaty to solve problems that have many factors and many criteria. AHP is a structured method related to the decision-making process on complex problems, which consists of many alternatives such as projects, actions, and scenarios. AHP is developed according to the hierarchical structure of several alternative combinations in decision-making. For example, knowledge, experience, and intuition. This method can provide an opportunity for everyone to make decisions on various types of problems [23].

IV. Research Result and Discussion

A. The Weighting of Characteristics and Sub-characteristics of ISO 25010:2011

Determination of the characteristics and sub-characteristic weights of the ISO 25010:2011 quality model was carried out to measure the quality of the Halodoc software. Determination of this weight is done before evaluating the quality of the software. This Weighting method is based on previous research [24]. Weight determination will be carried out on 8 characteristics and 29 sub-characteristics of the ISO 25010:2011 quality model. Determination of the weights will use software assistance, namely Web-based AHP with the link address: https://bpmsg.com/ahp/ahp-calc.php.

B. The weighting of Characteristic of ISO 25010:2011

The results of determining the weight characteristics of the ISO 25010:2011 quality model obtained a weight of 8 characteristics as shown in Fig. 2.

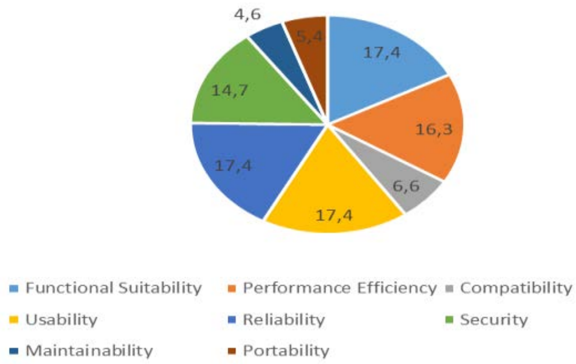

Fig. 2. Result of Weighting Characteristics of ISO 25010:2011.

Characteristics of Functional Suitability, Usability, and Reliability each get a weight of 17.4%. Characteristic of Performance Efficiency gets a weight of 16.3%. Security characteristic gets a weight of 14.7%. Compatibility characteristic gets a weight of 6.6%. Portability characteristic gets a weight of 5.4% and Maintainability gets a weight of 4.6%.

After determining the weight of each characteristic, the determination of the weight of the sub-characteristics will be carried out on each characteristic of Functional Suitability, Performance Efficiency, Compatibility, Reliability, Security, Maintainability, and Portability. This journal will write 4 characteristics tests that will be used for weight determination and application testing. Those characteristics are Performance Efficiency, Reliability, Security, and Usability.

1) The weighting of performance efficiency: Three sub-characteristics that will be included are Resource Utilization, Time Behavior, and Capacity. The next step is to determine the priority of the three sub-characteristics.

The sub-characteristics of Resource Utilization and Time Behavior have the same important priority so that they get priority 1. It's because Time Behavior is used to examine the processing time when performing a function and Resource Utilization is used to determine the number of hardware resources used to carry out the function.

The Time Behavior sub-characteristic has a higher priority than Capacity with a priority of 5, which is of medium importance. It's because Time Behavior is used to examine the processing time when performing a function while Capacity is used to determine the maximum amount of hardware resources used to carry out the function.

The Resource Utilization sub-characteristic has a higher priority than Capacity and gets priority 3, which is slightly more important. This is because Resource Utilization is used to find out the number of hardware resources used to carry out functions while Capacity is used to find out the maximum number of hardware resources used by the software.

The result of determining the priority of sub-characteristics can be seen in Fig. 3. Time Behaviour gets a weight 48.1%, Resource Utilization gets 40.5%, and Capacity gets 11.4%.

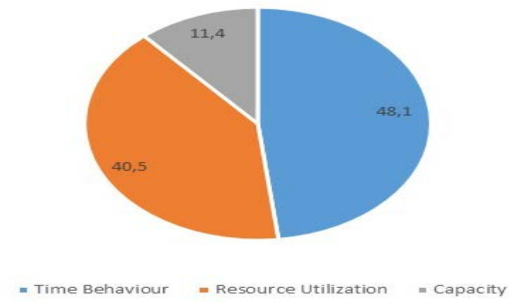

Fig. 3. Performance Efficiency Weighting Result.

2) The weighting of reliability: The four sub-characteristics that have been included are Availability, Maturity, Recoverability, and Fault Tolerance. The next step is to determine the priority of the four sub-characteristics.

The Maturity and Fault Tolerance sub-characteristic is slightly more important than the Availability and Recoverability sub-characteristics. This gives Maturity and Fault Tolerance priority 3. This is because Maturity is used to determine software maturity in various conditions and Fault Tolerance is used to determine whether the software can run properly even if an error occurs while Availability is a sub-characteristic that serves to test software availability and Recoverability is used to determine whether the software can recover data and systems as desired if a failure occurs.

The sub-characteristics of Maturity and Fault Tolerance have the same level of importance so that they get priority 1, which is equally important. This is because Maturity is used to determine the maturity of the software under various conditions and Fault Tolerance is used to determine whether the software can run properly even if an error occurs.

The sub-characteristics of Availability and Recoverability have the same level of importance so that they get priority 1, which is equally important. This is because Availability is a sub-characteristic that serves to test the availability of software and Recoverability is used to find out whether the software can recover data and systems as desired if a failure occurs.

The result of determining the priority of sub-characteristics can be seen in Fig. 4. Maturity gets a weight 37.5%, Availability gets 12.5%, Fault Tolerance gets 37.5%, and Recoverability gets 12.5%.

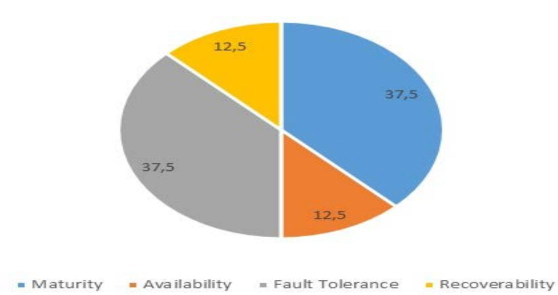

Fig. 4. Reliability Weighting Result.

3) The weighting of security: The five sub-characteristics included are Integrity, Non-repudiation, Confidentiality Authenticity, and Accountability. The next step is to determine the priority of the five sub-characteristics.

The sub-characteristics of Confidentiality, Integrity, Authenticity have the same level of importance so each of them get priority 1, that means is equally important. This is because the Confidentiality sub-characteristic ensures that application data can only be modified and accessed by authorized parties. Integrity ensures the prevention of alteration or deletion of information by unauthorized parties, and Authenticity ensures that the identity of the subject can be proven as stated by the subject.

The Confidentiality sub-characteristic is slightly more important than the Non-repudiation and Accountability sub-characteristic so it get priority 3 that means it is slightly more important. This is because the Confidentiality sub-characteristic ensures that application data can only be modified and accessed by authorized parties. While non-repudiation is used to determine the extent to which events or actions can be proven to have occurred and Accountability is used to know that the actions of an entity can be traced to that entity in a unique way.

The Integrity sub-characteristic is slightly more important than the Non-repudiation and Accountability sub-characteristic with priority 3. This is because Integrity ensures the prevention of changes or deletion of information by unauthorized parties while Non-repudiation is used to determine the extent to which events or actions can be proven to have occurred and Accountability is used to know that the actions of an entity can be traced to that entity in a unique way.

The Authenticity sub-characteristic is slightly more important than the Non-repudiation and Accountability sub-characteristic with priority 3. This is because Authenticity ensures that the identity of the subject can be proven as stated by the subject whereas Non-repudiation is used to determine the extent to which events or actions can be proven to have occurred and Accountability is used to know that the actions of an entity can be traced to that entity in a unique way.

Non-repudiation sub-characteristics with Accountability have the same level of importance so they have priority 1. This is because these two sub-characteristics have the same two objectives, namely to prove and record activities that have been carried out so that they can be proven.

The result of determining the priority of sub-characteristics can be seen in Fig. 5. The Confidentiality gets a weight 27.3%, Integrity also gets 27.3%, Non-repudiation gets 9.1%, Accountability get 9.1%, and Authenticity get 27.3%.

4) The weighting of usability: Six sub-characteristics of Usability are Learnability, Appropriateness Recognizability, User Error Protection Operability, Accessibility, and User Interface Aesthetics. These six sub-characteristics will be included then be prioritized.

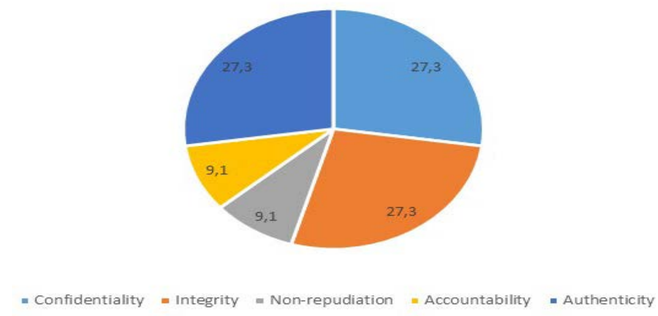

Fig. 5. Security Weighting Result.

The Learnability and Operability sub-characteristic are more important than the Appropriateness Recognizability sub-characteristic so Learnability and Operability obtain priority 3, slightly more important. Learnability test software can be learned easily or not and Operability tests whether the software is easy to operate or use by users while Appropriateness Recognizability is used to test the extent to which users can recognize whether a software fits their needs.

User Error Protection sub-characteristics and User Interface Aesthetics with Appropriateness Recognizability sub-characteristics obtain priority 1 which means the same importance. User Error Protection tests whether the software can protect users from making mistakes, User Interface Aesthetics tests whether the software interface allows pleasant and satisfying interactions for users, and Appropriateness Recognizability is used to test the extent to which users can identify whether a software fits their needs.

The Appropriateness Recognizability, Learnability, and Operability sub-characteristic are more important than the Accessibility sub-characteristic with priority 3. Appropriateness Recognizability is used to test the extent to which users can recognize whether a software fits their needs, Learnability tests software that can be learned easily or not, and Operability sub-characteristics test whether the software is easy to operate or use by the user while Accessibility tests whether the software can be accessed or not by the user.

Learnability sub-characteristics with Operability sub-characteristics obtain priority 1 which means the same importance. Learnability sub-characteristics test the software can be learned easily or not and Operability sub-characteristics test whether the software is easy to operate or use by users.

Learnability sub-characteristics with User Error Protection and User Interface Aesthetics sub-characteristics get priority 1 which means the same importance. The Learnability sub-characteristics tests whether the software can be learned easily or not, the User Error Protection Sub-characteristics tests whether the software can protect users from making mistakes, and User Interface Aesthetics Sub-characteristics test whether the software interface allows pleasant and satisfying interactions for users.

Operability sub-characteristics with User Error Protection and User Interface Aesthetics sub-characteristics get priority 1 which means the same importance. The Operability sub-characteristics test whether the software is easy to operate or use by the user, the User Error Protection sub-characteristics test whether the software can protect users from making errors and User Interface Aesthetics sub-characteristics test whether the software interface allows pleasant and satisfying interactions for users.

User Error Protection sub-characteristics with User Interface Aesthetics sub-characteristics obtain priority 1 which means the same importance. The User Error Protection sub-characteristic tests whether the software can protect users from making mistakes and the User Interface Aesthetics sub-characteristic tests whether the software interface allows for a pleasant and satisfying interaction for the user.

The User Error Protection sub-characteristic is more important than the Accessibility sub-characteristic with priority 3, a little more important. The User Error Protection sub-characteristic tests whether the software can protect users from making mistakes while Accessibility tests whether the software can be accessed by the user.

Sub-characteristic User Interface Aesthetics with sub-characteristic Accessibility get priority 1 which means the same importance. Sub-characteristics of User Interface Aesthetics test whether the software interface allows pleasant and satisfying interactions for users and Accessibility tests whether the software can be accessed or not by the user.

The result of determining the priority of sub-characteristics can be seen in Fig. 6. The Appropriateness Recognizability gets a weight 13.5%, Learnability and Operability each get 22.4%, User Error Protection gets 18,2 %, User Interface Aesthetics gets 15.8%, and Accessibility gets 7.7%.

C. Testing Halodoc Application

This section will describe the testing for Halodoc Application. Type of testing will be used depend of the sub-characteristic. Some of the test will be using software for testing.

1) Performance efficiency characteristic test: Time Behavior testing for Halodoc application will use Black-Box testing. This test is carried out with the aim of knowing how long the response and process time can reach the requirements when carrying out the function. This test is carried out using web-based testing software, namely testproject.io.

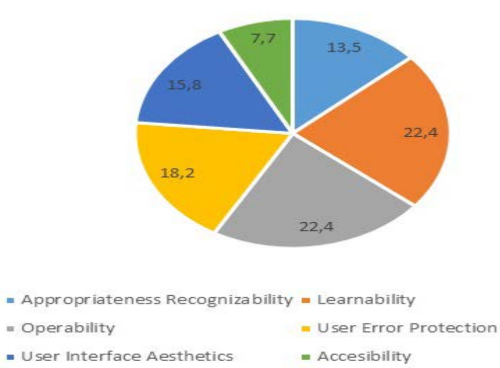

Fig. 6. Usability Weighting Result.

Resource Utilization testing will use Black-Box testing. This test is carried out with the aim of knowing the extent to which the amount and type of resources are used by the software when carrying out its functions in order to meet the requirements. The test for checking RAM allocation for the application will use Apptim Software.

Capacity testing will use Black-Box testing. This test is carried out with the aim of knowing the extent to which the maximum limit of a product or system parameter meets the requirements. The test for checking maximum RAM usage for the application will use Apptim Software.

Fig. 7 will show the score for each sub-characteristics of Performance Efficiency. The total score of Performance Efficiency characteristic will be calculated based on the accumulation sub-characteristics score. This result can be seen in Table I.

2) Reliability characteristic test: Maturity test for the Halodoc application will use stress testing. This test is carried out with the aim of knowing how much the software can meet the requirements for reliability in normal operation. This test is carried out using the Monkey feature on the Android SDK. Monkey can be used to stress testing applications by entering random but repetitive commands.

Availability test for Halodoc application will use stress testing. This test is carried out with the aim of knowing the extent to which the product can operate and can be accessed when needed for use. This test is done by accessing the website version of the Halodoc application using the Jmeter tool to create 100 virtual users. The website version was chosen to facilitate testing with Jmeter and because of the Availability characteristic; it aims to find out if the application can be accessed when needed.

Recoverability test will use Black-Box testing. This test is conducted with the aim of knowing in the event of a failure or breakdown, the system or application can recover the affected data directly and reestablish the desired system state.

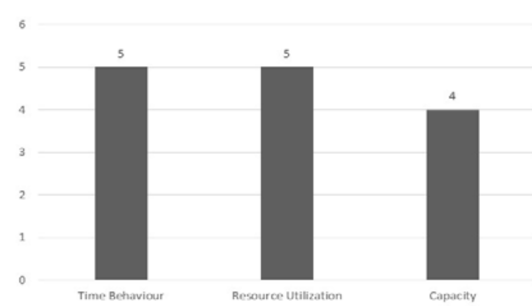

Fig. 7. Performance Efficiency Sub-characteristics Score.

TABLE I. PERFORMANCE EFFICIENCY TEST RESULT

No.	Sub-Characteristics	Weight	Score	Total Score
1	Time Behaviour	48.1%	5	48.1% * 5 = 2.405
2	Resource Utilization	40.5%	5	40.5% * 5 = 2.025
3	Capacity	11.4%	4	11.4% * 4 = 0.456
Total Score of Performance Efficiency				4.886

Fault Tolerance test will use stress testing for Halodoc application testing. This test is carried out with the aim of knowing the extent to which the system or application can operate properly despite software or hardware errors.

Fig. 8 will show the score for each sub-characteristics of Reliability. Total score of Reliability characteristic will be calculated based on accumulation sub-characteristics score. This result can be seen in Table II.

3) Security characteristic test: Confidentiality test will use Black-box testing. This test is carried out with the aim of knowing how the system or application can ensure that data can only be accessed by those authorized. In this test case, it is done by logging into the Halodoc application.

Integrity test for the Halodoc application will use Black-Box testing. This test is carried out with the aim of determining if a system or application can prevent modification of computer programs or data and prevents unauthorized access. In this case, testing will be carried out to change user profile information and modify the Halodoc program.

Non-Repudiation test will use the observation method. This test is carried out with the aim of knowing the extent to which an action or event can be proven to have occurred so that the event or action cannot be denied in the future. The test is carried out by observing the logs or history in the Halodoc application.

Accountability test will use the observation method. This test is carried out with the aim of knowing the ability of the software to distinguish the original user or not. Testing is done by observing user activities when logging into the application.

Fig. 9 will show the score for each sub-characteristics of Security. Total score of Security characteristic will be calculated based on accumulation sub-characteristics score. This result can be seen in Table III.

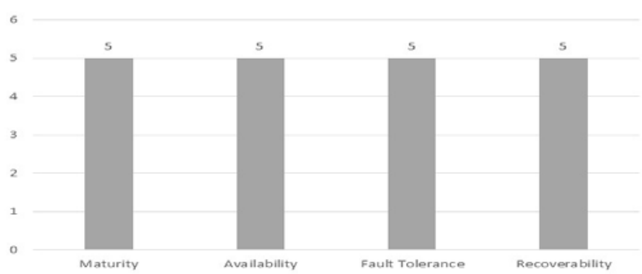

Fig. 8. Reliability Sub-characteristics Score.

TABLE II. RELIABILITY TEST RESULT

No.	Sub-Characteristics	Weight	Score	Total Score
1	Maturity	37.5%	5	37.5% * 5 = 1.875
2	Avalability	12.5%	5	12.5% * 5 = 0.625
3	Recoverability	12.5%	5	12.5% * 5= 0.625
4	Fault Tolerance	37.5	5	37.5% * 5 = 1.875
Total Score of Reliability				5

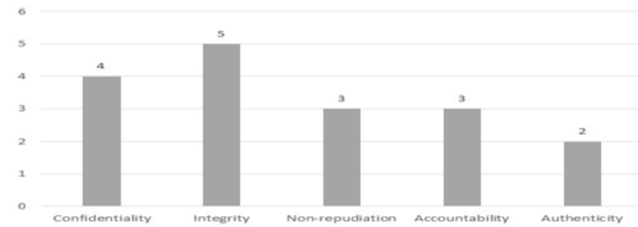

Fig. 9. Security Sub-characteristics Score.

TABLE III. SECURITY TEST RESULT

No.	Sub-Characteristics	Weight	Score	Total Score
1	Confidentiality	27.3%	4	27.3% * 4 = 1.092
2	Integrity	27.3%	5	27.3% * 5 = 1.365
3	Non-repudiation	9.1%	3	9.1% * 3 = 0.273
4	Accountability	9.1%	3	9.1% * 3 = 0.273
5	Authenticity	27.3%	2	27.3% * 2 = 0.546
Total Score of Security				3.549

4) Usability characteristic test: Usability characteristic testing for the Halodoc application will use 6 sub-characteristics. The sub-characteristics are Operability, Appropriateness Recognizability, User Error Protection, Learnability, Accessibility, and User Interface Aesthetics. The questionnaire that will be used in this test is based on J.R. Lewis Usability Questionnaire that has been modified by previous research [24]. Testing these characteristics will use a questionnaire distributed to respondents who use the Halodoc application. The results of the questionnaire test will then pass the validity and reliability testing using the IBM SPSS version 20 program.

Research sample selection will use the random sampling technique. The sampling method used refers to the solving approach. The result is 100 samples required for usability testing. The questionnaire will be distributed to 100 people who have used the Halodoc application.

The data from the questionnaire that has been collected will then be tested for validity and reliability. The results of the validity test can be said to be valid if the value obtained exceeds the value of the r table with sample (N) = 100 at a significance of 5% with an r value of 0.197. The questionnaire each question passes this validity question. The next step is to test the Reliability of the questionnaire. Reliability testing is carried out after the validity test results get valid results. This step is done after testing the validity of using SPSS Tools. The result can be seen in Fig. 10.

The results of the reliability test obtained the value of Cronbach Alpha of 0.931. If you look at Table IV, the reliability test results get the Very High category. This means the questionnaire that has been filled out by the respondent is reliable.

Case Processing Summary

		N	%
Cases	Valid	100	100.0
	Excluded[a]	0	.0
	Total	100	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.931	17

Fig. 10. Usability Questionnaire Reliability Test Result.

TABLE IV. RELIABILITY INDEX CRITERIA

No.	Interval	Criteria
1	0.000 - 0.200	Very Low
2	0.201 - 0.400	Low
3	0.401 - 0.600	Enough
4	0.601 - 0.800	High
5	0.801 - 1.000	Very High

Appropriateness Recognizability is done to find out how much users can recognize whether a product fits their needs. The sub-characteristic of Appropriateness Recognizability has 3 questions out of 17 questionnaire questions asked to respondents with a total of 300 votes. From Fig. 11, the Appropriateness Recognizability sub-characteristic gets the most votes for Agree with 152 votes out of 300 votes.

Learnability is carried out to determine if the software is easy to learn by users. Learnability sub-characteristics have 3 questions out of 17 questionnaire questions asked to respondents with a total of 300 votes. From Fig. 11, the Learnability sub-characteristic gets the most votes for Agree with 133 votes out of 300 votes.

Operability is carried out to determine if the software is easy to control and use by users. Operability sub-characteristics has 3 questions out of 17 questionnaire questions asked to respondents with a total of 300 votes. From Fig. 11, the Operability sub-characteristic gets the most votes for Agree with 137 votes out of 300 votes.

User Error Protection is carried out to determine if the system protects users from making mistakes. User Error Protection sub-characteristics has 2 questions out of 17 questionnaire questions asked to respondents with a total of 200 votes. From Fig. 11 can be seen that the User Error Protection sub-characteristic gets the most votes for Agree with 80 votes out of 200 votes.

Aesthetic User Interface is carried out to determine if the user interface allows pleasant and satisfying interactions for users. User Interface Aesthetic sub-characteristics has 4 questions out of 17 questionnaire questions asked to respondents with a total of 400 votes. Fig. 11 shows that the Aesthetic User Interface sub-characteristic gets the most votes for Agree with 191 votes out of 400 votes.

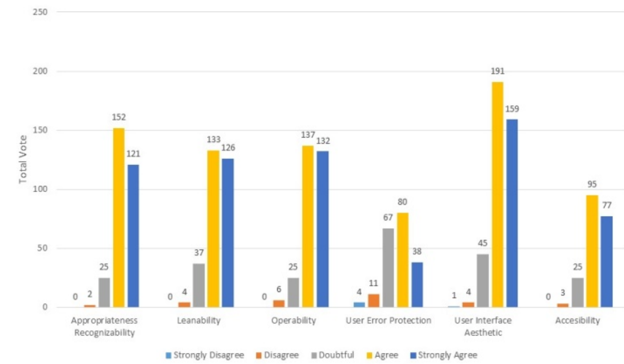

Fig. 11. Usability Sub-Characteristics Votes.

Accessibility is carried out to determine if the software is easily accessed by users. Accessibility sub-characteristics have 2 questions out of 17 questionnaire questions asked to respondents with a total of 200 votes. From Fig. 11, the Aesthetic User Interface sub-characteristic gets the most votes for Agree with 191 votes out of 200 votes.

Total score of Security characteristic will be calculated based on accumulation sub-characteristics score. This result can be seen in Table V.

TABLE V. USABILITY TEST RESULT

No.	Sub-Characteristics	Weight	Score	Total Score
1	Appropriateness Recognizability	13.5%	4	13.5% * 4 = 0.54
2	Learnability	22.4%	4	22.4% * 4 = 0.896
3	Operability	22.4%	4	22.4% * 4 = 0.896
4	User Error Protection	18.2%	4	18.2% * 4 = 0.728
5	User Interface Aesthetic	15.8%	4	15.8% * 4 = 0.632
6	Accesibility	7.7%	4	7.7% * 4 = 0.308
Total Score of Usability				4

D. Halodoc Application Total Result

The testing and assessment of the characteristics of the ISO 25010:2011 on the Halodoc application have been carried out. The value of each characteristic can be seen in Fig. 12.

The next step is to calculate the total value for the Halodoc application. Table VI shows the calculation of the total value obtained by the Halodoc application by combining the 8 characteristics of the ISO 25010:2011 model.

The quality test assessment of the software, namely Halodoc, uses the ISO 25010:2011 method with 8 characteristics and 29 sub-characteristics, the assessment is carried out using various testing models such as Black-Box testing, stress testing, observation, and questionnaires distributed to 100 respondents. The Halodoc application gets a score of 4,515 out of a total score of 5. This score is good for Halodoc software because it is only less than 0.5 points adrift to get the maximum score.

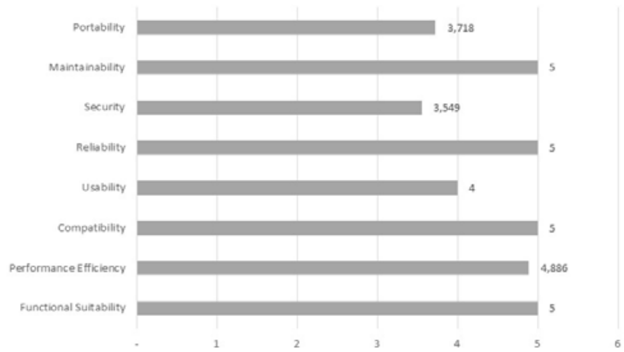

Fig. 12. ISO 25010:2011 Characteristics Score.

From Fig. 12 can be seen that the Security and Portability Characteristic result is enough but need improvement. Performance Efficiency and Usability already get a good result but still, it can be improved.

TABLE VI. TOTAL SCORE OF HALODOC APPLICATION

No.	Sub-Characteristics	Weight	Score	Total Score
1	Functional Suitability	17.4%	5	17.4% * 5 = 0.87
2	Performance Efficiency	16.3%	4.886	16.3% * 4.886 = 0.796
3	Compatibility	6.6%	5	6.6% * 5 = 0.33
4	Usability	17.4%	4	17.4% * 4 = 0.696
5	Reliablity	17.4%	5	17.4% * 5 = 0.87
6	Security	14.7%	3.549	14.7% * 3.549 = 0.522
7	Maintainability	4.6%	5	4.6% * 5 = 0.23
8	Portability	5.4%	3.718	5.4% * 3.718 = 0.201
Halodoc Application Total Score				4.515

V. CONCLUSION AND SUGGESTION

A. Conclusion

Halodoc application testing using the ISO 25010:2011 model has been successfully carried out. Characteristics of Functional Suitability, Performance Efficiency, Compatibility, Usability, Reliability, Security, Portability, and Maintainability with 29 sub-characteristics used to assess Halodoc applications. Tests are carried out using several testing methods ranging from Black-Box testing to testing the characteristics of Functional Suitability, Performance Efficiency, Compatibility, Security, Portability, and Maintainability. Stress testing is also carried out to test the characteristics of Reliability. The questionnaire method was used for usability testing which was distributed to 100 respondents using the Halodoc application.

Characteristics of Functional Suitability, Compatibility, Reliability, and Maintainability managed to get the best score, namely, 5. The Usability and Performance Efficiency Characteristics managed to get scores of 4 for Usability and 4.886 for Performance Efficiency. This characteristic has received good values but can still be improved. Characteristics of Portability and Security get a value of 3.718 and 3.549 respectively. The total score obtained is 4.515 from a total value of 5 for the Halodoc application. This value indicates that the Halodoc application has good software quality, although some characteristics still need development and improvement. The results of this test can be taken into consideration for Halodoc application developers to correct deficiencies and improve what is already good.

B. Suggestion

Testing the quality of the Halodoc application using the ISO 25010:2011 method can still be developed again. The use of tools or tools for testing can be added again. Such as tools for testing the characteristics of Reliability, Security, and Portability. The testing method used can also be added, such as the penetration testing method for security characteristics. Sub-characteristics that were not used in this study can also be added for further research. This can be done so that the shortcomings that occur in the application can be known in detail.

VI. LIST OF ABBREVIATIONS

TABLE VII. ABBREVIATIONS LIST

No.	*Abbreviations*	Meaning
1	AHP	Analytical Hierarchy Process
2	ISO	International Organization for Standardization
3	SPSS	Statistical Package for the Social Sciences
4	SQA	Software Quality Assurance
5	UI	User Interface

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APPENDIX

A. *List of Question in Usability Questionnaire*

TABLE VIII. USABILITY QUESTIONS

No.	*Sub-characteristic*	Question
1	Appropriateness Recognizability	Overall I am satisfied using the Halodoc application?
2	Appropriateness Recognizability	How to use the Halodoc application is very simple?
3	Appropriateness Recognizability	The information obtained is very easy to understand?
4	Learnability	I feel very fast in getting health information on this application?
5	Learnability	I find it very easy to learn the Halodoc application?
6	Learnability	The information provided by the Halodoc application is very clear?
7	Operability	Can I get health information quickly using the Halodoc application?
8	Operability	Is it easy to get information about health on the Halodoc application?
9	Operability	The information I get on the Halodoc application helps to get the health information I want to know?
10	User Error Protection	If an error occurs, the application informs the error that occurred?
11	User Error Protection	Whenever I make a mistake, can I recover quickly?
12	User Interface Aesthetic	Am I comfortable using the Halodoc application?
13	User Interface Aesthetic	The layout in the Halodoc application display is very clear?
14	User Interface Aesthetic	Halodoc application display is very easy?
15	User Interface Aesthetic	I like the look of apps like Halodoc?
16	Accessibility	The ability of the application to complete all the functions in it make me satisfied?
17	Accessibility	Overall I am satisfied with the Halodoc application?

The Novel CPW 2.4 GHz Antenna with Parallel Hybrid Electromagnetic Solar for IoT Energy Harvesting and Wireless Sensors

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***Abstract*—The design and implementation's novelty simultaneously utilizes the antenna's frequency, polarization, and feed structure to maximize the harvested RF energy and become a microstrip communication circuit for wireless sensor or communication systems in IoT devices. In addition, the optimization of the parallel circuit configuration has a voltage doubler model with an integrated parallel system and thin-film solar cells. Implementation of the antenna structure has two-line feeds in one antenna. Usage both feeds have the same function as CPW circular polarization. Another advantage is that there is no miss-configuration when installing the port exchanges when using both output ports simultaneously. The 2-port antenna has an area of 1/2 per port (where accessible wavelengths work well at the 2.4 GHz frequency). It has been shown to achieve a relatively narrow bandwidth of 86.5 percent covering WiFi frequency band networks and IoT communications. It does not require additional filters and analog matching circuits that cause power loss in the transmission process in parallel voltage doubler circuits. Integrating a reflector on the CPW antenna with two ports for placement of thin-film solar cells provides antenna gain of up to 8.2 dB. It provides a wide beam range with directional radiation. Using a multi-stage parallel to increase voltage output and integrated with a thin-film solar cell converter proves efficient in the 2.4 GHz frequency band. When the transmission power density is -16.15 dBm with a tolerance of 0.023, the novel energy harvester configuration circuit can produce an output voltage of 54 mV dc without adding solar cell energy. And Integrated thin-film solar cell a light beam of 300 lux in the radiation beam area of -16.15 dBm, the energy obtained has a value of 1,74467V. It also shows that the implementation of this configuration can produce an optimal dc output voltage in the actual indoor and outdoor ambient settings. The optimization of antenna implementation and the communication process with Multiple signal classifications improves the configuration of antennas that are close to each other and have identical phase outputs. It is instrumental and efficient when applied to IoT devices.**

Keywords*—*Double CPW antenna; energy harvesting; wireless sensors; IoT communications

I. Introduction

Most mobile-based device implementations connect wireless sensor networks, actuators in implementing Internet-of-Things (IoT) communication, manufacturing processes, health care, and transportation. However, the challenges of powering these devices require battery usage, recharging, and power support across multiple sensors. However, it still requires conventional charging, and battery replacement is becoming very expensive and unsustainable[1][2]. Using energy harvesters to collect energy from environmental sources outside of IoT devices is the most feasible solution. Energy harvesting such as solar, thermal, vibration, piezoelectric, magnetic, and RF are just forms of exploration in collecting energy sources. Film Solar cells with integrated ambient RF or electromagnetic energy collection have better performance than single-source harvesting, based on the principle of using an integrated antenna to harvest energy in the environment and harvesting embedded solar energy indoors or outdoors[3][4]. It can be scaled to multiple nodes either in parallel or partially having high functionality. The technology related to electromagnetic energy harvesting is a wireless power transmission process in which the emitted electromagnetic energy comes from a specific source to be harvested. In addition, the harvesting of electromagnetic energy can be done by collecting sources of electromagnetic radiation present, such as in WLAN systems or other wireless networks, whose use is legally free[5][6]. Harvesting ambient RF energy to support independent IoT devices is becoming practical, increasing devices becoming wireless RF sources.

Most previous research on antennas as electromagnetic energy harvesters only considers partial antenna designs in the one-time harvesting process. They have not utilized antennas as a dual function domain and linear antenna integration. For example, a recent paper presents High-Efficiency Rectenna Broadband for Energy Harvesting RF environment [7]. It only has the function of harvesting single polarized and electromagnetic energy for single antenna use. Consequently, it is essential to use multi-function and optimization of parallel antennas and have directional radiation coverage and power gain to optimize the collection of RF energy in the environment. Antennas with multi-polarization properties can maximize the available RF energy so that absorption from the transmission with random polarization can be well in the IoT device communication system. The configuration has the aim of collecting polarized varying ambient RF energy while minimizing polarization mismatch. It has an alternative to collect ambient RF energy integrated antenna as optimization needs to combine thin-film solar cells [8].

This study proposes a single narrow band electromagnetic environmental energy harvesting device that functions as an electromagnetic energy harvester and wireless sensor[9], especially in IoT devices at the WiFi frequency (2.36-2.44 GHz) integrated with reflectors embedded with The thin-solar cells. Then optimized with parallel configurations to address

*Corresponding Author

the challenges of charging and replacing batteries in IoT devices. Some of our work is: 1) exploiting the antenna function and spatial domain simultaneously, as well as adjusting the polarization to optimize the function as support for sensors or wireless IoT communication and RF energy harvesting, 2) proposing an integrated CPW antenna with a reflector as placement of thin-film solar cells as a canopy on the back of the antenna with the schematic in Fig. 1, 3) provides a design for a compact high gain. To ensure that the dc output voltage can reach 1.2V -1.7V when integrated. [10][4] Provide a comparison of our technology with previous work in outdoor and indoor environments.

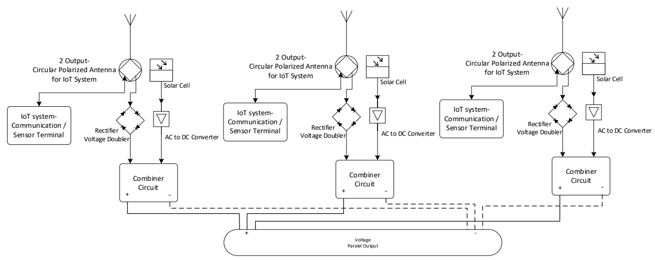


Fig. 1. Schematic of CPW 2.4 GHz Antenna with Parallel Hybrid Electromagnetic Solar for Energy Conversion Systems.

II. Parallel Hybrid Electromagnetic Circuit

A new 2.4 GHz rectenna was developed and exhibited with optimal configuration dimensions and structures to maximize IoT communication for wireless sensor and voltage. A line of 3 microstrips connects the antenna and the rectifier; Integrating Base Element on FR4 epoxy white paper with a rhombus-shaped slot. Integration is also done on the patch antenna with a radiator in the form of a double patch.

A. Paralel multi Stage Voltage Doubler Paralel Circuit

The rectifier circuit determines the effectiveness of the AC-to-DC Electromagnetic conversion; therefore, this circuit is an essential part of the Hybrid Solar Electromagnetic circuit. The requirements of a suitable rectifier are low power application, high sensitivity, and high voltage handling capability [11]. A rectifier configuration typically consists of an ideal 50-ohm connection for maximum voltage level delivery, a rectifier component (diode) for AC-to-DC Electromagnetic conversion) [12][13]. The only use of power forward in a rectifier circuit is a standard single series diode. The RF power of the antenna is reduced as it passes through the stripline and diode circuits, so direct current is created from the remaining energy.

Due to low power density and unmet circuit bias criteria, single series diode arrays (as opposed to single shunt array diodes) are inefficient for ambient electromagnetic energy collection. In addition, the breakdown voltage of a single diode rectifier is limited, limiting the power handling capacity of the circuit. As a result, as shown in Fig. 2, a rectifier with a voltage multiplier is shown, which implements a modified diode arrangement on a single shunt. The waveform is rectified half-cycle at the positive pole by the diode circuit D1, through the power supply voltage collection at the voltage C1. After the shunt diode D2 rectifies the negative half-cycle of the waveform, the power absorption is at C2. The power voltage C2 can be transferred to C1 in a single series diode arrangement producing a certain energy level around C1 from an almost simultaneous peak voltage considering the values of RJ, CJ, and Rs on the diode.

As the breakdown voltage of the rectifier increases, the power level of the empirical peak conversion voltage of the rectifier also increases. Furthermore, a partial rectification of the D2 waveform produces a bias voltage of D1 and reduces the input electromagnetic power level (thus increasing the power voltage level sensitivity). The voltage multiplier rectifier was selected for the rectenna design using a bridge type to optimize the voltage output and its architecture in Fig. 4. There are two diodes in each of the two branches.

Some of the results of the previous diode can generate a bias connection of each diode. Use settings that lower the total electromagnetic power consumption. The maximum power level can increase power sensitivity using the half-wave rectifier technique and power level capacity optimization. The choice of the diode is crucial because it can be a significant source of charge voltage and affect circuit performance. Low power input signals (forward bias voltage: 20–100 mV at 0.1 mA) requiring a low bias voltage are ideal for low power applications; diode for parallel selection circuit using Schottky SMS7630.

Another part involved in this circuit is the point of the nonpolar capacitor. The capacitor used in this circuit is a type of Tantalum SMD with a working frequency greater than 2.4 GHz, making it easier to optimize both physically and in terms of calculations. At the same time, optimization [14] on the input impedance of the CMOS circuit chip with a voltage multiplier, where the measurement is challenging and has a reasonably complex stage. To optimize the voltage output in the circuit design, the capacitor on the circuit will cross the load. The output voltage determines the value of the transient response speed for DC leveling.

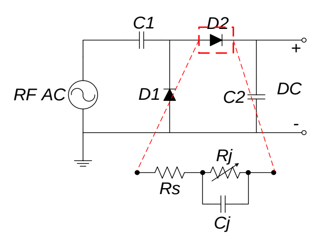


Fig. 2. Voltage Doubler Series on Rectifier.

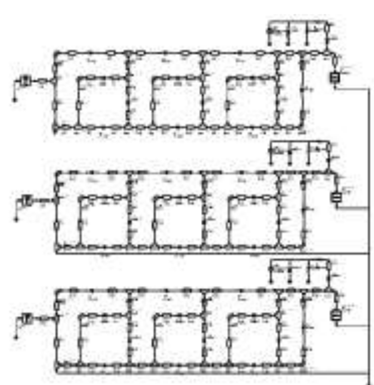


Fig. 3. Simulation using Advanced Design System (ADS) Software.

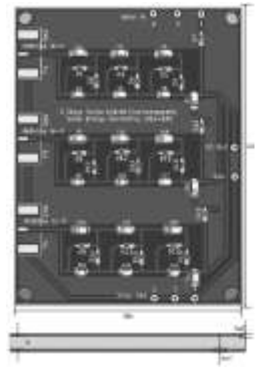


Fig. 4. Implementation of Rectenna Circuit.

TABLE I. HYBRID ELECTROMAGNETIC SOLAR CIRCUIT - 3 STAGE PARALLEL VOLTAGE DOUBLER STRUCTURE PARAMETERS

No.	Component	Label	Value and Material
1	*Non Polar SMD Stage Capacitor*	*C1, C3, C5, C8, C12, C16, C10, C14, C18*	100uF - Tantalum
2		*C2, C4, C6, C9, C13, C17, C11, C15, C19*	10nF - Tantalum
3	*Stage SMD Diode*	D1-D19	RB551VM-30
4	*Solar Cell Thin Film*	*hl1*	1 mm - Copper
5	*Circuit Dimension*	*Wu,Lu*	55.5 mm, 72 mm
6	*Copper Conductor*	*hl2*	0.035 mm - Copper
7	*Substrate Semiconductor*	*h*	1.6 mm - Phenolic white paper (FR-4)

The most dominant simulation instrument is the Advanced Design System (ADS) software for the configuration and design in Fig. 3. Based on the simulation analysis, the 3-parallel voltage multiplier stage is most suitable for this implementation. For implementing the Rectenna Circuit using the KiCAD software next, the building blocks of printed circuit boards are Basic Epoxy Fiberglass (FR4) (PCB). Table I lists the components in the circuit. Circuit elements consist of active and passive components. Connections to PCBs and other modules using 50 ohm SMA connectors are given special attention because they are related to matching.

B. Microstrip CPW Antenna

Due to the variability of electromagnetic environmental signals, antennas for RF or electromagnetic energy harvesting usually have special requirements. The need for broad direct rays and circularly polarized antennas require an antenna capable of receiving input waves with varying polarization and phase changes. In addition, in antenna performance, it is crucial to consider the quality of the standing wave ratio because hybrid circuits can apply higher working frequency signals and determine conversion at DC voltage levels. The desired frequency band range is 2.3–2.5 GHz. The conventional method for the standing wave ratio is to utilize a bandpass filter between the antennas of a hybrid circuit rectifier to pass another standing wave on a less clear broadband signal in previous studies[15][16]. However, rejecting broadband signals is much more complex than rejecting narrowband signals, so the proposed antenna uses narrowband. Broadband filters can increase the physical size of the rectenna and large insertion loss voltages [17][18]. As a result, the strategy in this research is to connect a narrowband antenna with a half AC to DC converter integrated with solar cells to get them working frequency focus. The reference antenna (initial setpoint) consists of a planar double pole with two pairs[19]; after optimization and striping the lines, cut square-shaped slots on each pole area to modify the surface, which is 95mm long and 99mm wide.

Furthermore, the second harmonic impedance must be reduced or increased by changing the impedance on the smith chart of the square-shaped slot. The plane of the micro-ground strip antenna, which is orthogonally and behind the microstrip feed line antenna, has two line feeds on it. Ansys HFSS software uses the FEM method to construct microstrip antennas. After calculation and optimization, the high-order parameters are omitted, and the ideal performance of the proposed antenna is shown in Fig. 5.

The partially independent antennae is a narrow band dual-line L feed patch probe antenna, and the 2-port antenna structure is constructed using two antenna elements. Each 2-port antenna configuration has a thin-film solar cell integrated with a reflector to increase gain and optimize radiation. The antenna implementation has microstrip lines printed on the rear, while the 45-degree line feed curve and rectangular cutouts edge are etched on the front. Feed ports 1 and 2 are also shown in Fig. 5. The antenna section comprises a small feed-in with a square cut slot antenna with the exact specifications as a CPW antenna at 2.4 GHz. The length and width of the slot are approximately half a wavelength by design. The optimized ground width in a typical slot mode is a quarter of a wavelength. In optimizing the frequency shift and the patch polarization filter, the slots are optimized into square pieces, and the soil in the area around the square is reduced to a certain extent. The 45-degree line feed antenna works in one wavelength perimeter mode.

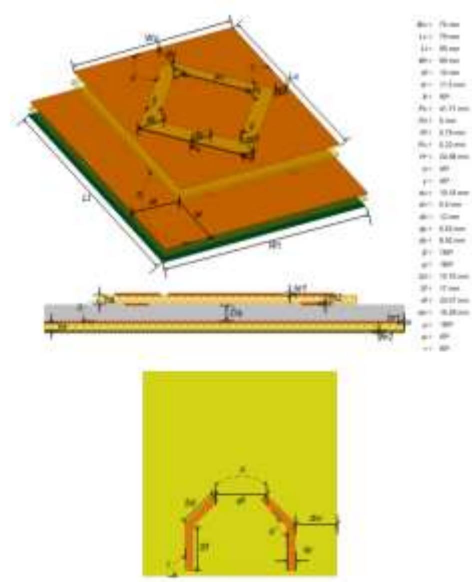


Fig. 5. Structure of Implementation of Double Port CPW Antenna.

To other advantages, the proposed antenna design can adjust the center frequency of the two-port S parameter almost independently under the matching conditions. To tunning it by varying the square side of the ground plane (Prd) in Fig. 6 with length Prd = Pr-de, where de is the diagonal edge at the end ground. As illustrated in Fig. 4, the initial simulation of varying Prd = {29mm, ... ,33 mm} refers to Fig. 5, while the value of Pr without is adopted for the initial antenna prototype before the optimization.

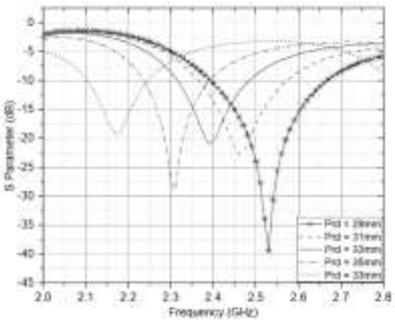


Fig. 6. Tuning Matching Antenna Frequency based on Prd Variation.

However, the frequency adjustment needs to be optimized again by increasing the accuracy of the center value. The optimization with varying dimensions of edge slot on the length square side of the ground. It is interdependent between the horizontal edge Pu and the vertical edge Pt with a symmetrical value resulting from optimizing circular polarization. Figure 5 illustrates with a dimensional accuracy value of up to 0.01mm to obtain frequency accuracy in the variation of dimensions Pu={5.14mm,…., 5.26 mm} and Pt = {5.70,…..,5.82}, with Pr and Pu values resulting from the final optimization of the antenna, which has been independently combined with other antenna parameters in Fig. 7.

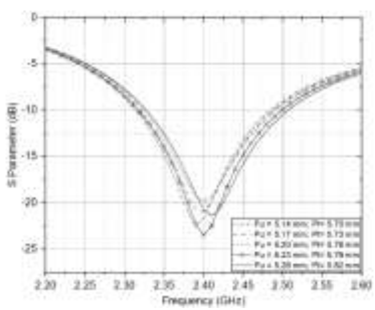


Fig. 7. Increasing the Accuracy of the S parameter Focus Value based on the Edge Ground Dimension Optimization.

The substrate, reflector, and conductor on the patch antenna using a CPW polarized SMA-probe in a narrow band are directly a 1.6 mm thick phenolic patch positioned above the ground and supported by a substrate on a white paper dielectric constant of 4.2. The materials parameters are shown in Table II.

We used a thick air substrate to optimize distance with the integrated thin-film solar cell to increase the radiation gain and beamwidth between the patch and the reflector. The proposed 2-port antenna has an average antenna area of 1:2 per port. It represents a compact multiport antenna design with an open-space wavelength at 2.4 GHz. Therefore, our basis for calculating the average antenna area per port on the design in free space wavelengths: 1) the primary substrates of the proposed patch antenna are fr4 and antenna; 2) the multiport antenna design is compact, expressing the Freespace wavelength because the nearest antenna port is often connected by air with the requirement with layered material.

TABLE II. MATERIALS STRUCTURE OF THE ANTENNA CONFIGURATION

No.	Parameters	Values	Materials
1	*ha*	1.6 mm	Copper
2	*ht1*	0.035 mm	Copper
3	*ht2*	0.035 mm	Phenolic white paper (FR-4)
4	*δ*	90°	
5	*Ds*	5 mm	Air
6	*hr*	1.6 mm	Copper
7	*hr1*	0.035 mm	Copper
8	*hr2*	0.035 mm	Phenolic white paper (FR-4)

III. PERFORMANCE AND ANALYSIS

A. Double port CPW Antenna Performance

Based on measurements, Fig. 8 shows the value of the reflection coefficient with the representation of the S parameter at each port of the antenna. The analysis is carried out first on the narrowband reflection coefficient. The rectangular graph shows a frequency shift between |S11|. Measurements and 0.1 GHz range. Port 1 has a bandwidth of -15 dB of 192 MHz (2.353-2.545 GHz), while Port 2 has a -15 dB of 161 MHz (2.36-2.521 GHz) bandwidth. From 2.453 to 2.821 GHz, bandwidth still below -15 dB has a bandwidth of 148 MHz (78 percent) overlap. Overall, the reflection coefficient with the representation of the S parameter value of -15 dB and the spectrum power level test of the antenna can work at a frequency of 2.4GHZ, which is shown in Figure 13. The spectrum reception and S Parameters, the antenna based on regulation, can work well for IoT and Energy harvesting applications.

Another performance advantage of the dual-port mode is represented in Fig. 8. Optimizing the microstrip antenna using a reflector integrated with a thin-film solar cell can generate the power gain value in the 2.3–2.5 GHz free IoT communication band with a significant advantage of 8.2 dB at 2.4GHz. The overall gain level is between 8 and 8.6 dB, which is higher than a standard microstrip antenna with an average of 3dB. Optimization of the distance and dimensions of the reflector, which integrates with the thin-film solar cell on the 180-degree position antenna, makes the power signal collection on the radiation element not distorted. Due to the demands of optimal IoT communication, it utilizes circular polarized antennas. It can receive and transmit vertical, horizontal, and other than the two electromagnetic waveforms, so necessary to obtain an axial ratio value below 3dB. Fig. 9 shows the comparison of values between horizontally polarized transmission waves and vertically, expressed by the value of the axial ratio below about 3dB of variation as a representation of circular polarization[16]. Thus the optimization resulting in CPW or total circular polarization is obtained from a symmetrical base plane with electromagnetic filter effect radiation on the slot on-ground configuration.

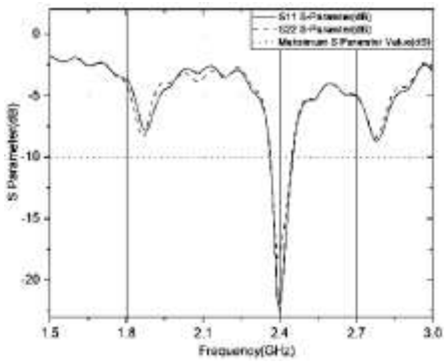


Fig. 8. S Parameters of CPW Dual-Port Microstrip Antenna.

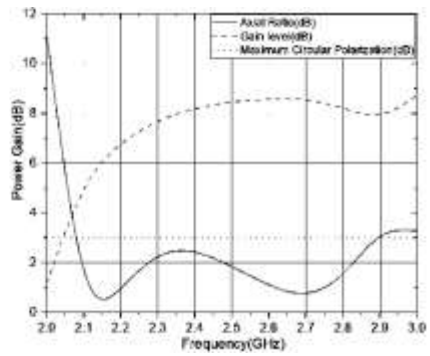


Fig. 9. Gain and Axial Ratio CPW Dual-Port Microstrip Antenna.

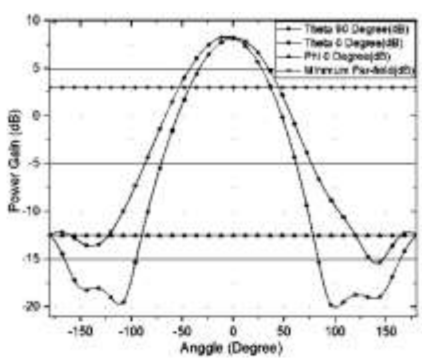


Fig. 10. Radiation Pattern of CPW Dual-Port Microstrip Antenna-Rectangular Plot.

Fig. 10 represents the performance analysis of the antenna implementation based on the typical radiation pattern at an operating frequency of 2.4 GHz inside and on the surface. The performance analysis results match the statistical value of the power distribution level in the direction of the intended device quite well. The radiation pattern is transformed at the position θ with an angle of 90 degrees and θ at 0 degrees. The reference antenna position faces the Z ordinate with a condition of 0 degrees. Hence, Z ordinate radiation the antenna has one lobe with the most significant power level value. It has a minimal sidelobe value on the radiation viewing angle transformation at ϕ on 0 degrees so that the polarization of the Antenna is Directional. To simplify the implementation of the rectenna in the analysis using Fig. 11 using polar coordinates to describe the degree of exposure of the area. The directional radiation pattern of the antenna indicates that the antenna can be used as an access point in IoT applications to generate energy and communicate directly. The optimization on the square ground plane of the dual-port antenna allows simultaneous vertical and horizontal polarization. The proposed antenna has the following advantages: small overall size, optimal bandwidth, and not cross-polarization.

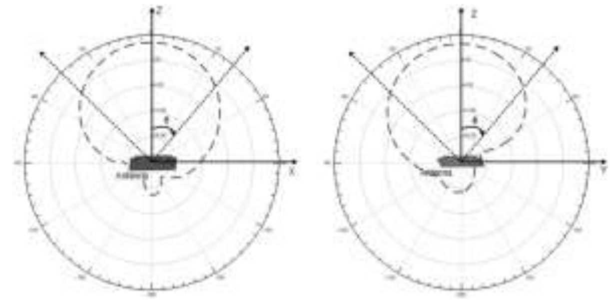
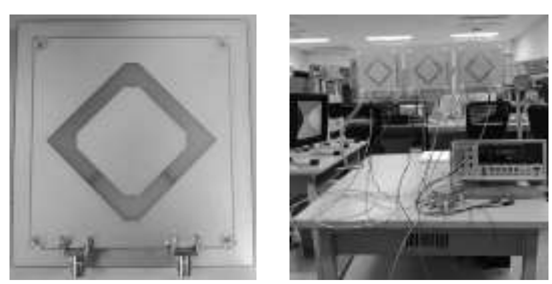


Fig. 11. Radiation Pattern CPW Dual-Port Microstrip Antenna-Polar Plot.

B. *Performance Electromagnetic-Solar with Parallel CPW antenna Circuit Integrated*

In the parallel circuit performance test, the receiving antenna is connected to the rectifier circuit via an SMA connection with a characteristic impedance of 50 ohms. The produced rectenna was tested in the laboratory, as illustrated in Fig. 12. The performance of the rectifier circuit as determined by the AC-DC voltage conversion value and the output frequency is illustrated in Fig. 13 and 14, respectively, used the same experimental data collection technique with different configurations of performance measurements as in Fig. 12(b).

The rectifier circuit, Receiver antenna, and thin film can be directly connected because the dual output feed antenna and the input port of the rectifier circuit have the same impedance as the output port. In addition, the circuit configuration has a compact implementation for other ports as the IoT communication feed line. However, to make measurements more movable in the laboratory using a coaxial cable with an adjustable impedance. The results of the performance measurements of the rectenna are in Fig. 12(b). a signal generator connected to the SHRP RZ1AT4A antenna as a microstrip antenna used in industry is the signal source to spread electromagnetic waves in the laboratory area. Then the antenna absorption value is expressed by testing the spectrum in Fig. 13, which works well at a frequency of 2.4 GHz, which consists of -16.15 dBm, -23.66 dBm, and -33.89 dBm, because testing the signal spectrum is also very important when used in the communication process on IoT devices.



(a) (b)

Fig. 12. (a) Antenna Implementation and (b) Configuration Circuit Testing.

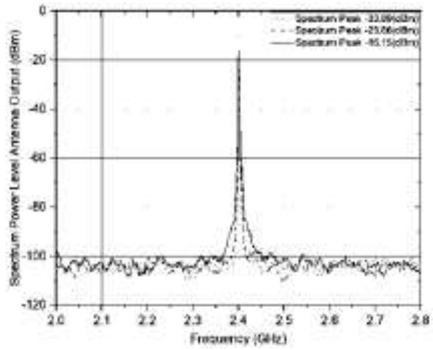


Fig. 13. Antenna Spectrum Test at a Frequency of 2.4 GHz.

The absorbed energy is amplified using a voltage doubler with a parallel and simultaneous configuration with a maximum absorption rate of -16.15 dBm antenna and a frequency range of 2.0 GHz to 2.8 GHz. At the primary working frequency of 2.4 GHz, the transmitting antenna is a beam with a power level of 20 dB.

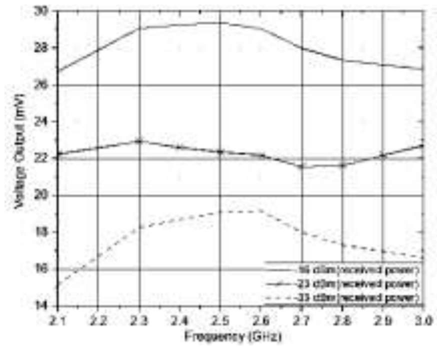
At the input power of -16.15 dBm, the output voltage with an electromagnetic field source in the single rectenna circuit configuration with 3 stage doubler has a value of 29.3 mV. The parallel circuit configuration has a value of 52 mV, as shown in Fig. 14. Fig. 14 shows that the increase is quite significant if the configuration is optimized to be parallel with the analysis of equation 1, which shows an efficient circuit performance, where the value of R_{iL} is the value of the resistance of the circuit. $V_{Pcircuit}$ is the output voltage of the rectifier circuit, R_0 is the internal resistance of the transmission medium, μ is the characteristic coefficient of the circuit voltage quantity with a value of 0.6, and n_P is the number of parallel lines sources in the circuit.

$$V_{Pcircuit} = \mu \boldsymbol{n_p} \frac{n_0 \boldsymbol{V_0}}{n_0 \boldsymbol{R_0} + \boldsymbol{R_{iL}}} \boldsymbol{R_{iL}} \tag{1}$$

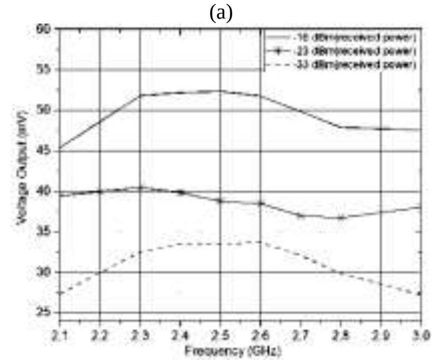
Fig. 16 shows the performance of the Parallel 3 Stage Voltage Doubler Circuit. It generates an output voltage and AC voltage conversion from the rectenna with variations in the power level collected at the same value on two 2.4GHz ports based on the variable transmit power source, namely, the RF source and light intensity. First, the circuit performance test is comprehensively tested with various light conditions in Fig. 15.

When the light intensity received by the thin-film solar cell increases, the output voltage increases whether used in single or parallel configurations. The output voltage in the configuration proposed in this study, a parallel configuration with the integration of thin-film solar cells, has an output voltage of 1.74467V with a light-emitting source of 300 lux in Fig. 16. The parallel circuit has the advantage of increasing the voltage up to 80% compared with a single [20] configuration. In addition, integration with solar cells can also increase the power up to 25 times if only relying on electromagnetic sources [21]. In this case, the electromagnetic source is inferior, according to the source in the IoT device.

The optimization of the design and implementation significantly improves compared to previous studies [22][10]. This Reference only relied on a single configuration and one particular application. The increase in the voltage value in the circuit test on the independent variable shows that it can work well, both from one energy source and two sources of energy.



(a)



(b)

Fig. 14. Antenna Output Voltage in an (a) Single and (b) Parallel Three-Stage-Voltage Doubler Circuit.

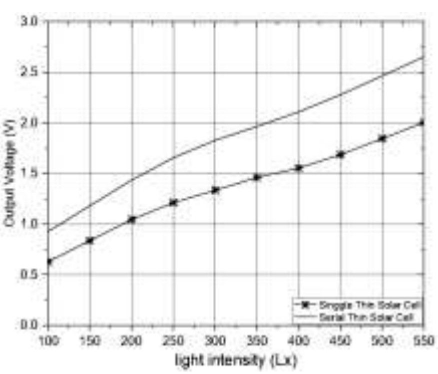


Fig. 15. AC to DC Conversion Test on Solar Cell Film.

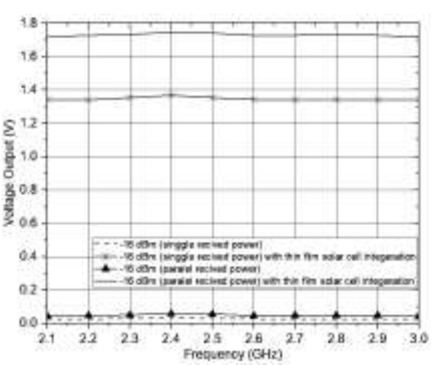


Fig. 16. Performance of Integrated Parallel Rectenna-thin Film Solar Cell Output Voltage.

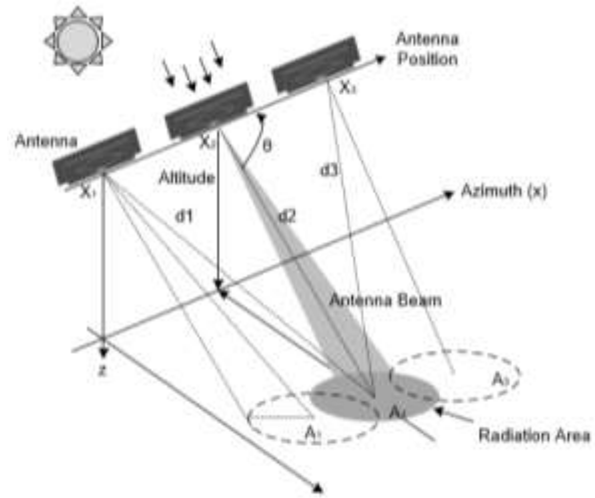


Fig. 17. Overall Implementation Analysis of the Integrated Rectenna-thin Film Solar Cell Prototype.

Fig. 17 shows the overall implementation analysis scheme of the prototype that has been tested in the laboratory. Implementing energy harvesting with the integration of thin-film solar cells is estimated as exposure to sunlight, 100 lux when cloudy to 1000 lux maximum. This range is following the performance test of the lowest voltage limit on the prototype for implementation. In addition, the implementation of the energy harvesting and communication process must adjust the radiation angle based on Fig. 10 and 11 of the antenna element radiation patterns. The optimum main lobe value at the antenna altitude is θ of 48 degrees, with overlapping antenna beam coverage areas. However, the antenna has almost the same phase in IoT communication and has a close position [23]. Therefore, it is necessary to analyze the signal with high accuracy to determine the number and direction of arrival of the antenna signal by using multiple signal classification analysis for Linear Array elements assuming the antenna's position with the number of transmitting sample signals analysis 1000 times and four source antennas, one antenna as a reference. Azimuth antenna on identical antenna elements based on Fig. 5, then the array manifold a(θ) is determined:

$$\mathrm{a}(\boldsymbol{\theta}) = \begin{bmatrix} 1 \\ e^{j2\pi d_1 \sin\theta_1/0.0125} \\ e^{j2\pi d_2 \sin\theta_2/0.0125} \\ e^{j2\pi d_3 \sin\theta_3/0.0125} \end{bmatrix}$$

Where d is the distance from a common reference point in the array and the azimuth coordinate antenna $\boldsymbol{\theta}$ that the direction measured from the perpendicular to the array, so if applied to multiple antennas with the transmission on communication devices with **F** is the amplitude at the 2.4GHz frequency of the antenna devices.

$$\begin{bmatrix} \mathbf{X_1} \\ \mathbf{X_2} \\ \mathbf{X_3} \\ \mathbf{X_4} \end{bmatrix} = [\mathrm{a}(\theta_1) \quad \mathrm{a}(\theta_2) \quad \mathrm{a}(\theta_3) \quad \mathrm{a}(\theta_4)] \begin{bmatrix} \mathbf{F}_1 e^{j15.085\times10^9 t} \\ \mathbf{F}_2 e^{j15.085\times10^9 t} \\ \mathbf{F}_3 e^{j15.085\times10^9 t} \\ \mathbf{F}_4 e^{j15.085\times10^9 t} \end{bmatrix}$$

Signal transmit of device source with random amplitude on covariance matrix:

$$\boldsymbol{s} = \begin{bmatrix} -0.2523 - 4.0111i & -3.0320 + 0.3830i & \dots & -1.3591 + 2.3441e-13i \\ 0.4964 + 7.8909i & 2.6104 - 0.3297i & \dots & 0.4605 - 7.9429e-14i \\ -0.2283 - 3.6299i & 1.6989 - 0.2146i & \dots & 1.9914 - 3.4346e-13i \\ -0.4224 - 6.7140i & 2.4543 - 0.3100i & \dots & 2.1928 - 3.7827e-13i \end{bmatrix}$$

With resultant steering vector between incoming signals$\mathbf{F}_1 e^{j15.085\times10^9 t}$ and **A** is steering matrix $\mathrm{a}(\boldsymbol{\theta})$, than $\mathrm{a}(\boldsymbol{\theta})$ *is* $\chi = \mathbf{A}\times\mathbf{s}$ dan χ^* ensemble average so $\overline{\chi_1\chi_1^*}$, $\overline{\chi_2\chi_2^*}$, $\overline{\chi_3\chi_3^*}$, $\overline{\chi_4\chi_4^*}$ Autocorrelation with the Rss. Then Rss autocorrelation input signal itself and the other cross-correlation value on the signal on the assumption of the signal plane then the covariance matrix for the incoming signal:

$$\overline{\chi\chi^*} = \begin{bmatrix} \overline{\boldsymbol{\chi_1\chi_1^*}} & \overline{\chi_1\chi_2^*} & \overline{\chi_1\chi_3^*} & \overline{\chi_1\chi_4^*} \\ \overline{\chi_2\chi_1^*} & \overline{\boldsymbol{\chi_2\chi_2^*}} & \overline{\chi_2\chi_3^*} & \overline{\chi_2\chi_4^*} \\ \overline{\chi_3\chi_1^*} & \overline{\chi_3\chi_2^*} & \overline{\boldsymbol{\chi_3\chi_3^*}} & \overline{\chi_3\chi_4^*} \\ \overline{\chi_4\chi_1^*} & \overline{\chi_4\chi_2^*} & \overline{\chi_4\chi_3^*} & \overline{\boldsymbol{\chi_4\chi_4^*}} \end{bmatrix} = \mathbf{A}\,\mathbf{R}\mathrm{ss}\,\mathbf{A}^* + \textit{power noise}$$

Then, extract the signal information using the Eigenvector of **A Rss A*** and the Eigenvector of noise power to generate the signal eigenvalues and the noise eigenvalues. We can describe the value noise subspace from the ***D*** matrix for the eigenvalue.

$$\boldsymbol{D} = \begin{bmatrix} 8.8141e-05 & 0 & 0 & 0 & 0 \\ 0 & 9.7605e-05 & 0 & 0 & 0 \\ 0 & 0 & 1.010e-04 & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \dots & 1.4814 \end{bmatrix} \approx \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & \ddots & 0 \\ 0 & 0 & 0 & \dots & 1 \end{bmatrix}$$

Then describe each **Rank** on the signal eigenvalues and eigen noise = **Ei** to determine the trash hold value of the signal. From this treatment, we can obtain a spectrum picture of each signal using the multiple signal classification equations 2.

$$P = \frac{1}{\mathrm{a}^*(\boldsymbol{\theta})\cdot \mathbf{E}_i \cdot \mathbf{E}_i^* \cdot \mathrm{a}(\boldsymbol{\theta})} \qquad (2)$$

The spectrum generated can be analyzed of each incoming signal spectrum result and the angle of origin signal even though the phase is almost identical, and the position is close to each other seen in Fig. 18. The spectrum shows a signal from the antenna with a directional arrival angle of $1/\mathrm{Norm}^2$ on each power signal. Information appears at 61, 92, 125, and 180 degrees for the analysis sample. Thus, the analysis can provide an efficient solution to the proposed configuration using a liner position antenna with circular antenna specifications when working as an IoT communication for wireless sensors antenna and energy harvester.

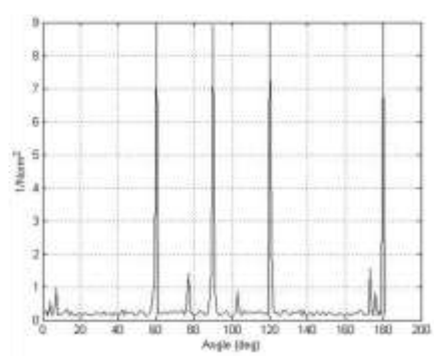


Fig. 18. Spectrum Analysis of Incoming Signals on Multiple Antennas.

IV. Conclusion

This article is based on performance tests and a new analysis of IoT Energy Harvesting and Wireless Sensors using 2.4 GHz CPW Antenna with Parallel Hybrid Electromagnetic Solar. A 2.4 GHz CPW rectangular dual-port antenna with IoT Wearable broadband, direction power beamwidth, and high gain is used as the receiving antenna. The proposed configuration includes a 2.4 GHz CPW rectangular dual-port antenna rectifier circuit based on IoT communication and the concept of parallel voltage doubling with an integrated thin-film solar cell. The performance of the microstrip antenna input and output of the S parameters of network feed with S11 -18.02 and dB S21 -24.7 dB, gain value of 11dbi, and axial ratio value of 2.46. According to these tests, the configuration of the rectifier and antenna circuits has a very narrow operating frequency range. And can be used effectively in any direction based on the radiation polarization. In addition, the integrated Rectenna has a compact design and is easy to apply. In the energy harvester performance test at the input power of -16.15 dBm, the output voltage with an electromagnetic field source, the single rectenna circuit configuration with 3 stage doublers has a value of 29.3 mV, and the parallel circuit configuration has a value of 52 mV. In addition, the output voltage in the configuration proposed in this study, which is a parallel configuration with the integration of thin-film solar cells, has an output voltage of 1.74467V. This configuration has the advantage of increasing the voltage up to 80% compared to the single configuration. In addition, integration with solar cells can also increase the temperature up to 25 times if only relying on electromagnetic sources. Based on the implementation analysis, the configuration energy harvester with thin-film solar cell integration can work up to at least 100 lux exposures to sunlight. And the electromagnetic transmission area will work optimally at an angle of 48 degrees based on the radiation pattern, and the prototype of IoT communication analysis can be implemented. Multiple signal classification for Linear Array for circular polarization antenna with high accuracy to determine the spectrum of each incoming signal and the angle of origin of the signal even with almost the identical phase. In progress, the development of this prototype is to become more compact and work on the working frequency of other IoT devices so that there are more options to be implemented.

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Smart Air Pollution Monitoring System with Smog Prediction Model using Machine Learning

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***Abstract*—Air Pollution is a harsh reality of today's times. With rapid industrialization and urbanization, the polluting gases emitted by the burning of fossil fuels in industries, factories and vehicles, cities around the world have become "gas chambers". Unfortunately, New Delhi too happens to be among the most polluted cities in the world. The present paper designs and demonstrates an IoT(Internet of Things) based smart air pollution monitoring system that could be installed at various junctions and high traffic zones in urban metropolis and megalopolis to monitor pollution locally. It is designed in a novelistic way that not just monitors air pollution by taking varied inputs from various sensors (temperature, humidity, smoke, Carbon monoxide, gas) and but also presents it on a smart mirror. Its unique feature is the demonstration of a smog prediction model by determining PM10 (Particulate Matter 10) concentration using the most efficient machine learning model after an extensive comparison by taking into account environmental conditions. This data generated can also be sent as a feedback to the traffic department to avoid incessant rush and to maintain uniform flow of traffic and also to environmental agencies to keep pollution levels under check.**

Keywords—Air pollution; IoT; machine learning; smart mirror; temperature and humidity sensor

I. Introduction

Air pollution is one of the most significant causes of deaths worldwide. It claims seven million lives a year, mostly premature, and is a major driver of fatal non-communicable diseases like lung cancer, bronchitis asthma, heart attacks etc. [1]. It is a potential cause for allergies and causes irritation to the eyes, throat and skin. It also adversely affects climate change and a major cause for global warming that is responsible for drastic climatic catastrophes in the world. With rapid industrialization, urbanization, emergence of huge metropolises and megalopolises, pollution is ever increasing in the cities with cities in India especially Delhi NCR consistently featuring in the top most polluted cities of the world. The problem is further exacerbated in the winter season when the temperature, humidity and prevailing wind conditions provide favorable conditions for development of smog like conditions in most parts of North, North West and West India.

Air pollution is measured as the concentration of various gases in parts per million or ppm. Pollutants are of two kinds: primary and secondary pollutants. Primary pollutants are those which are released directly into the atmosphere in the form smoke from the industries and factories or exhausts from vehicles. Primary pollutants include ammonia, sulfur dioxide, carbon monoxide and nitrogen dioxide. Secondary pollutants are those which are comparatively harmless in the atmosphere, however, turn into toxic pollutants on reaction with atmospheric conditions. Some types of secondary pollutants are ground-level ozone, acid rain and nutrient enrichment compounds.

Multiple ways have been devised to measure air pollution. Currently, it is monitored with the help of Air Quality Index(AQI) that defines the air quality in terms of ranges of pollutants in air in parts per million. AQI can be considered as a yardstick that runs from 0 to 500. The higher is the AQI value, the greater is the level of air pollution and the greater is the health concern. The following Table I demonstrates the air quality suitability with the corresponding range of pollutant concentration.

In line with this system of measurement of Air pollution, the present paper implements an IoT based Smart Air pollution monitoring system that depicts the localized air pollution levels along with temperature and humidity levels on Smart Mirror. It also employs the most efficient Machine learning model for Smog Prediction and this predictive analysis can serve as a feedback to the traffic department to forecast possible traffic jams and environmental agencies to keep the pollution levels in check.

The paper has been logically arranged in different sections. Section II describes the previous literature in this theme with their relevant shortcomings that led to the improvement in this project. Section III describes the methodology of the system in detail with special emphasis on the different machine learning algorithms employed in the system. Section IV presents the results obtained and its extensive analysis describing the resolution of the most efficient algorithm and the consequent results obtained. Section V discusses the advantages of the developed system and discusses about its real time deployment. Finally, the paper sums up with a futuristic conclusion and applications in Section VI.

TABLE I. AIR QUALITY INDEX

Range (PPM)	Status
0-50	Good
51-100	Moderate
101-150	Unhealthy for sensitive groups
151-200	Unhealthy
201-300	Very unhealthy
301 and above	Hazardous

*Corresponding Author

II. Review of Literature

The section describes the different works in the broad thematic area of research. While many types of research have been carried out in this broad area, they suffer from some inadequacies and limitations. For instance, paper [2] proposes and develops an IoT based Air Quality Monitoring System for Smart Cities using Raspberry Pi. However, it does not calibrate the sensors which results in drastic difference in values as opposed to the values yielded in Air Quality Index (AQI). While the calibration of sensors is employed in [3], it only utilizes one sensor i.e. MQ135 gas sensor thus excluding an important primary pollutant Carbon Monoxide from its scope of study. The paper [4] also suffers from similar limitation though it has employed humidity and temperature sensor that was not utilized in [3].

Application of neural network has a restrictive scope, for instance, the study demonstrated in [5] is a predictive analysis through neural network to demonstrate the harmful effects of air pollution on the human body and larger scope of the environment is not covered. In paper [11] application of artificial neural network for predicting air pollution levels has been presented whereas paper [6] employs an algorithm uses RFID technology to track down vehicles that cause vehicular pollution with higher emissions and reports them to environmental agencies. Thus, a thorough comparative modeling has not been performed. Further, the system in [7] demonstrates a crude set up to display air pollution however its accuracy is compromised to balance the cost of the set up.

With quite a few papers in the area of monitoring, the paper [8] uses a remote server to store data related to air pollution levels. In [9], combinations of wireless sensor networks and electrochemical toxic gas sensors with RFID (Radio Frequency Identification) tagging have been utilized to understand the pollution levels in vehicular emissions. The study proposed in [10] uses seismic sensor to predict earthquakes and light and humidity to analyze the location weather conditions. Thus, these researches are limited to the ‘monitoring’ aspect of air pollution.

Predictive analysis through machine learning has been demonstrated in some of the researches that have been surveyed. In [12], the prediction of air pollution is restricted to the supervised learning algorithms. In [13], the authors have utilized deep learning but with a highly imbalanced dataset and have predicted generic air pollution that too with a lower accuracy without confirmation with a real time dataset. In [14] and [15], the research is limited to different variants of Long Short Term Memory (LSTM) models for Air quality prediction in Delhi and South Korea respectively than the system proposed in this paper of specific smog prediction. A hybrid model was tested for monitoring air pollution at Iran’s combined cycle power plant in paper [16]. In [17], a single machine learning model SVM (Support Vector Machine) has been employed to detect air quality in California with an already available dataset from the internet. While an improved weighted LSTM model has been utilized in [18], significant resources have been utilized for real world application and the performance parameters such as speed and machine cycles have been compromised for accuracy. Finally in [19], AdaBoost machine learning has been employed in Taiwan to monitor air quality.

The present paper hones upon the existing research and addresses the shortcomings of the previous research such as lack of sensor calibration, limited number of sensors, incomplete datasets, compromised accuracy of predictive modeling, lack of comparative analysis of predictive modeling, compromised speed and machine cycles and inefficiency of resources. The paper presents a comprehensive approach that monitors air pollution on a real time basis, by utilizing input data from a variety of sensors to cover all possible sources of air pollution. It translates the data through calibration of sensors and averaging the value of sensors for ambient air quality index. Finally, it displays the Air pollution data along with smog levels on a Smart Mirror that can be employed at various junctions and high traffic zones in the city. Taking this data as input as well as dataset from Internet, the most efficient trained machine learning model is employed for Smog prediction. Furthermore, based on the data presented, corrective measures can be taken by traffic department environmental agencies to improve air quality and reduce air pollution.

III. Methodology

The system has been designed as a multi input multi output system. The sensory data from variety of sensors employed are fed into the microcontroller which monitor the localized atmosphere and generate a dataset that is displayed on the dynamic Smart Screen i.e. Magic Mirror. The dataset acts as an input for the Smog Prediction Model that employs the most efficient Machine learning model for the predictive analysis.

As demonstrated in the block diagram in Fig. 1, the present paper utilizes Arduino Uno R3 employing ATMega328P as microcontroller for implementation of the system. Arduino is an interactive open source platform characterized by low cost and flexible hardware and software. Arduino Uno R3 is the reference model and widely used. It has ATmega328 microcontroller chip (8- bit) at 16 MHz, with 14 digital I/O pins and 6 analog input pins. It is usually powered through USB connection but can also be powered by DC power socket from batteries.

The inputs to the Arduino are fed from the various sensors to determine the local environmental conditions. The most important sensor is the MQ135 Gas sensor. It can sense Ammonia (NH_3), Nitrous Oxides (NOx), alcohol, Benzene, smoke, CO_2 and some other gases. It gives the output in the form of voltage levels.

Since carbon monoxide is a significant primary air pollutant and MQ135 has the limitation of not measuring CO data, MQ7 carbon monoxide sensor has also been employed. This further hones the air pollution data received by Arduino Uno and can establish better results. The MQ-7 sensor can measure CO concentrations ranging from 20 to 2000ppm. It possesses faster response time and a high sensitivity. The sensor's output is an analog resistance.

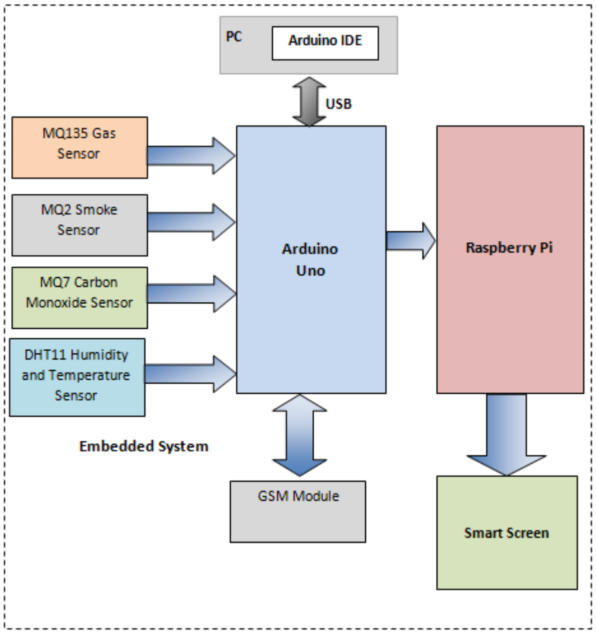

Fig. 1. Block Illustration of the Technique.

In high traffic zones such as highways, merging freeways and cross junctions, pollution probability is higher. This increases the probability of presence of smoke at the location. To measure the concentration of smoke in the location, MQ2 Smoke sensor has been utilized. The MQ2 gas sensor is an electronic sensor which is used to detect ambient gas concentrations such as smoke, LPG, propane, methane, hydrogen, alcohol and carbon monoxide in the range of 200-10000ppm. The gas sensor MQ2 is often referred to as a chemical resistor. It includes a sensing material whose resistance changes when the gas is in contact.

Finally, DHT 11 Humidity and Temperature sensor have been utilized to analyze the localized humidity and temperature conditions respectively. A requirement of digital temperature and humidity sensor that is simple and ultra-low-cost is fulfilled by the DHT11. A thermistor and a capacitive humidity sensor is used to test the air quality of surroundings and the result provided by the data pin in form of digital signal. It requires a careful timing in order to collect information but it's fairly easy to use.

The data from MQ7, MQ2 Smoke Sensor and DHT11 Humidity and Temperature Sensor is used to determine the smog levels in the location. Smog usually appears as haze in the air due to the mixture of smoke, gases, and particles. Smog formation is the result of the combination of stable atmospheric conditions, due to inversion, nitrogen oxides, and organic compounds reaction resulting in ozone and related compound and different kind of air pollution and the emissions from increasing number of cars. The most important step in this system design is the calibration of MQ135, MQ2 and MQ7 Gas sensor with respect to fresh air and then development of an equation that transforms output sensor voltage into corresponding PPM levels. For this, the average analog readings of the resistance from the sensor and converting it to the voltage are taken.

The data from Arduino R3 is fed into Raspberry Pi 3. The Raspberry Pi 3 is a Pi series development board that can be viewed as a single computer board. It works with the LINUX Operating System. It has a fast processing speed, and uses wireless Local Area Network (LAN) and Bluetooth and can set up a WIFI hotspot to connect to the internet. It has a dedicated Liquid Crystal Display (LCD) display port. All the above data are displayed on the smart screen/magic mirror specially designed for the same. Smart screen though previously developed multiple times provides basic facilities like displaying clock, news, weather using APIs. The proposed screen is especially designed to provide serial communication between Arduino and Raspberry Pi Screen.

Fig. 2 represents the schematic diagram of the air pollution monitoring system developed. It shows the pin connections and the schematic of the functioning of the system.

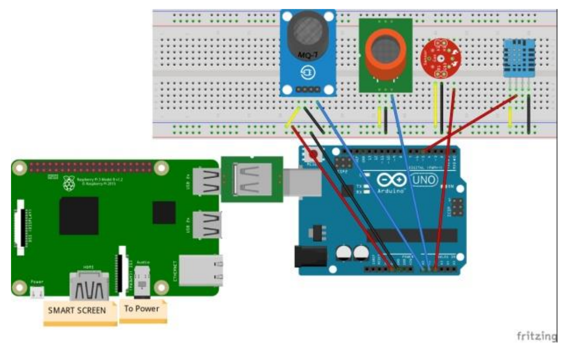

Fig. 2. Schematic Diagram.

A. Equations

The sensor gives raw value and it needs to be converted into PPM. The relation for the same is obtained from the (Rs/Ro) versus PPM graph as shown in Fig. 3. The resistance of these sensors changes in response to the concentration of gases, viz. value of resistance decreases in response to increase in gas concentration; taking MQ135 sensor graph as reference for calculation.

Ro is the value of resistance in fresh air and the value of Rs is the value of resistance at various Gas concentrations. After preheating the sensor, the important step is to calibrate the sensor in fresh air to find Ro; from circuit diagram in Fig. 4 of MQ135, applying Ohm's law.

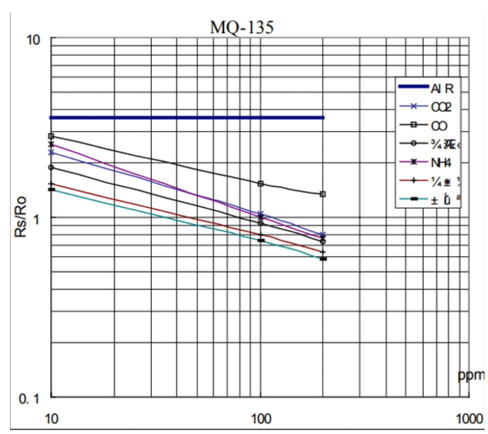

Fig. 3. Graph showing Rs/Ro Ratio for MQ-135 Sensor.

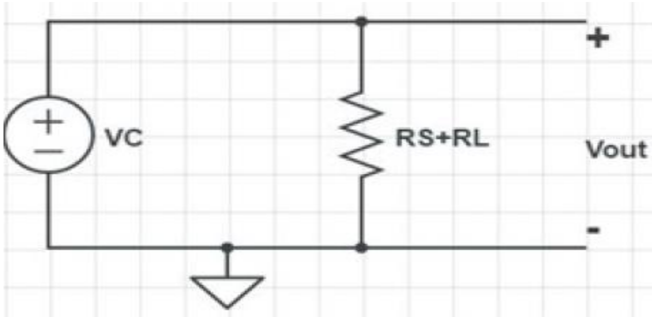

Fig. 4. Internal Circuit of MQ135.

$$V_{R_l} = \left[\frac{V_c}{R_s + R_l}\right] * R_L$$

$$V_{R_l} = \left[\frac{V_c * R_L}{R_s + R_l}\right] \quad (1)$$

$$V_{R_l} * (R_s + R_s) = V_c * R_L$$

$$(V_{R_l} * R_s) + (V_{R_l} * R_l) = V_c * R_L$$

$$(V_{R_l} * R_s) = (V_c * R_L) - (V_{R_l} * R_l)$$

$$R_s = \frac{(V_c * R_L) - (V_{R_l} * R_l)}{V_{R_l}}$$

$$R_s = \frac{(V_c * R_L)}{V_{R_l}} - R_l \quad (2)$$

Thus, the final equation in (2) is used to determine Rs.

From the graph above in Fig. 3, the resistance ratio Rs/Ro for fresh air is constant i.e. 3.6. To calculate Ro, Rs is to be found in fresh air, which is done by averaging the sensor raw reading and converting the same in volts and then using this volts value in equation (2) to obtain Rs, which is then used to find the Ro using Rs/Ro ratio of fresh air.

Now this Ro is used to find Ratio in presence of gas concentration. Using the Resistance ratio value in presence of gas, equivalent value of PPM for that particular gas can be determined from the graph.

To determine PPM from graph using resistance ratio, equation of line was applied on this log graph:

$$log_{10} y = m * log_{10} x + b \quad (3)$$

To find the slope, two points were selected from the graph. The points (200, 2.6) are and (10000, 0.75) from the LPG line. The formula becomes:

$$m = \frac{log y - \log(y_0)}{log x - \log(x_0)} \quad (4)$$

After solving (3) and (4), the values obtained were m= -0.318 and b= 1.13. Thus, the gas concentration using any ratio can be found using:

$$lo\ g(x) = \frac{lo\ g(y) - b}{m} \quad (5)$$

B. Smart Mirror

This paper presents the design and development of a smart mirror for displaying the air pollution based on Arduino sensor output. It provides a novel approach for establishing transmission between Arduino sensors and the Pi based Smart mirror which is based on node.js languages. The configuration file of the mirror was modified to incorporate the necessary parameters (port address, list of sensors and their output format) to make Arduino sensors value visible on magic mirror. The sensors value from Arduino is sent via serial communication in a standard format (understandable by mirror).

The mirror provides a natural means of interaction through which the commuters can control their movement based on the prevailing environmental condition in that area. The data displayed gives the real time conditions. The module for displaying the output is developed keeping in mind all the requirements. Fig. 5 shows the proposed Smart Mirror.

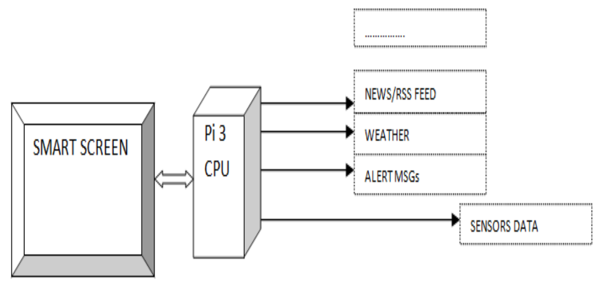

Fig. 5. Schematic Diagram of Smart Mirror.

C. Smog Prediction Model

Smog is one the important cause of severe air pollution. It is formed as a result of combination of smoke, fog and water vapor. Sudden appearance of smog and/or fog on the highway more often than not causes serious and sometimes fatal accidents. It can also aggravate health problems including problems with breathing and sleeping, as well as it can adversely damage the surrounding flora and fauna.

Smog Prediction analysis has been performed by testing and comparing six different Machine leaning models. In the first model, a general learning framework based on an ensemble strategy and artificial neural networks (ANNs) has been employed. Thus, ANN has been trained to predict the PM 10 concentrations which is the main cause of the occurrence of smog phenomena. For the neural network presented, carbon monoxide, temperature, relative humidity, PM concentration of previous day and smoke were fed as an input and the target is the present day PM10 concentration.

Various types of neural network architectures with varied number of hidden nodes were formed and tested to get the best network for each measurement station. Among the different types of ANN, feed forward network is employed. It is a type of artificial neural network in which nodes' connections do not form a loop. As a result, it differs from its descendant, recurrent neural networks. The information in this network flows exclusively in one direction: forward, from the input nodes to the output nodes, passing through any hidden nodes (if any). Multi-layer perceptron (a class of feed forward ANN) as shown in Fig. 6 demonstrated the best result.

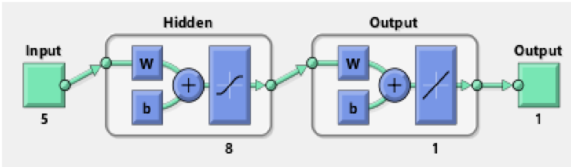

Fig. 6. Artificial Neural Network Trained using MATLAB.

The next modeling was performed using Support Vector Regression. It is a supervised learning algorithm that is used to predict discrete values. Support Vector Regression uses the same principle as the support vector machine (SVMs). The basic idea behind SVR is to find the best fit line. SVR was tested with different kernel functions. The function of kernel is to take data as input and transform it into the required form.

Linear Regression Algorithm was also trained and tested for the same dataset to determine accuracy and other comparison parameter. It is a supervised machine learning algorithm that carries out a regression task. Based on independent variables, regression models a goal prediction value.

An AdaBoost regressor was performed on the given dataset. It is a meta-estimator that starts by fitting a regressor on the original dataset, and then fits new copies of the regressor on the same dataset, but with the weights of instances modified based on the current prediction's error.

Stacking regression was also trained for this dataset. It is a technique for creating linear combinations of various predictors in order to enhance prediction accuracy. Under non-negativity restrictions, cross-validation data and least squares are used. It consists in stacking the output of individual estimator and use a regressor to compute the final prediction. Stacking allows using the strength of each individual estimator (base estimator) by using their output as input of a final estimator. RigdeCV and linear SVR was the base estimator for stacking regression and random forest was the final estimator.

Furthermore, Random Forest Regression, a supervised learning approach for regression was also trained and tested for predictive modeling with hyper parameter tuning. Hyper parameter tuning implies varying the hyper parameter (number of trees and number of features) selected with criterion parameter as “gini” and then “entropy”. Random Forest Regression uses the ensemble learning method that combines predictions from several machine learning algorithms to get a more accurate prediction than a single model. The algorithm has been demonstrated in Fig. 7.

Certain parameters were compared to be able to predict the most efficient model. The comparison of the model was performed using accuracy, Root Mean Square Error (RMSE) and correlation coefficient as shown in Table IV.

Accuracy is the measurement used to determine which model is best at identifying relationships and patterns between variables in a dataset based on the input, or training, data. Mean Square Error (MSE) is one of the simplest metrics used in regression. It is defined as the sum of the squares of the difference of the actual value to the predicted value or it is average squared errors of the prediction made. RMSE is defined as Square root of Mean square error. The square root minimizes the errors and RMSE is used instead of MSE as MSE does not give an accurate picture when data is noisy. Higher the value of RMSE lesser the accuracy of Supervised Learning methods, lower the value of RMSE higher the accuracy. For two variables, the Correlation Coefficient compares the distance of each data point from the variable mean and uses this to tell us how closely the relationship between the variables can be fit to an imaginary line drawn through the data.

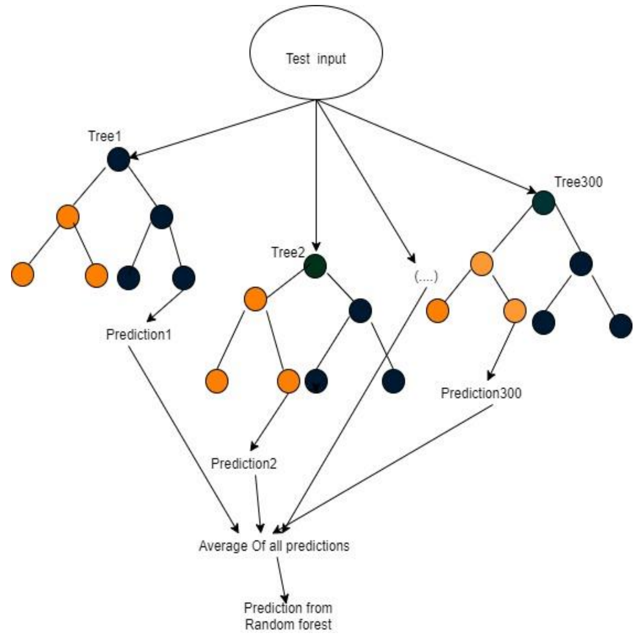

Fig. 7. Random Forest Algorithm.

The dataset was split as 75% training subset, and 25 % testing subset. The dataset comprises of around 400 values collected in the interval of three months by taking measurements at different durations of the day for temperature, humidity, Carbon monoxide, smoke, PM10 (previous day) and PM (current day). The use of sensors for temperature, relative humidity, carbon monoxide concentration and smoke with PM10 concentration of previous day obtained from the official site using Python command ensures the real time prediction of smog and utility of the deployed system after network has been trained. This ensures the continuous working of the system.

Huge amount of data is being generated continuously on the social web in the form of air quality and weather forecast. Thus, to improve our machine learning models prediction further Big data analytics can be employed which will improve the prediction done by trained models using physical sensor by utilizing social web data like weather tweets, geographic information, meteorological records and air quality records.

IV. Results

A. Sensors Measurement

1) After calibrations, Sensors were installed in an open terrace in the industrial area of Delhi NCR with reading taken at every 3 hours interval during the day as depicted in Fig. 8.

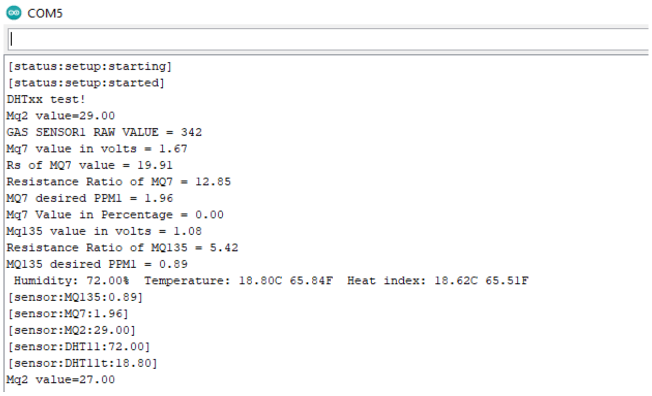

Fig. 8. Sensor Measurement.

2) *The readings from DHT and CO* sensor were compared with values measured by standard real time AQI values and are tabulated in Table II.

3) *The readings from MQ135* sensor were compared with Air quality monitor AM7000 and smoke sensor were compared with the standard values and tabulated in Table III.

4) *The RMSE value for temperature* is 0.644759 and for humidity is 0.953065. The RMSE value for CO is 0.5420.

5) The RMSE values for MQ135 sensor and Smoke is 0.8524 and 1.23051 respectively.

6) *Lower values of RMSE* obtained imply improved accuracy of Pollution monitoring than the previous research associated with monitoring.

TABLE II. COMPARISON OF MEASURED AND ACTUAL PARAMETERS

$Temp_M$ (°C)	$Temp_A$ (°C)	$Humidity_M$ (%)	$Humidity_A$ (%)	CO_M (ppm)	CO_A (ppm)
22.0	21.3	34.1	35.4	2.6	2.1
23.3	22.8	32.2	32.9	2	1.72
23.9	24.5	30.0	31.3	2.2	2.09
24.4	23.6	28.9	27.9	2.2	2.6
24.4	24.6	29.4	29.1	1.6	2.1
23.8	24.5	31.3	30.6	1.2	1.51
..	..	..	..	..	..
17.8	18.6	42.9	42.2	1.2	2.3

TABLE III. COMPARISON OF MEASURED AND ACTUAL PARAMETERS CO2 AND SMOKE SENSORS

$CO2_M$ (ppm)	$CO2_A$ (ppm)	Smoke $Sensor_M$ (ppm)	Smoke $Sensor_A$ (ppm)
2.1	2.96	54.05	52.8
2.82	3.42	65.7	64.1
6.9	8.5	58.45	56.3
15.4	15.1	57.2	56.9
12.5	11.9	53.8	53.4
..	..	..	..
4.9	4.4	55	55.3

B. Model Training and Comparison

1) *Six different machine* learning models were trained and tested viz. MATLAB ANN, Support vector regression, linear regression classifier, random forest regression, Adaboost regression and Stacking regression for predicting the PM10 concentration based on fed input.

2) *The following graph* in Fig. 10 shows the test value (PM10) result and actual values (PM10) for ANN and the result is considerably accurate.

3) *ANN is a statistical* model and the choice of ANN architecture, including the number and type of neurons, and the selection of a learning algorithm is very important to improve the accuracy.

4) *The ANN model* was trained multiple times with different number of hidden layers to determine the best suited number of hidden layers as shown in Fig. 7. The best suited was hidden layer with 8 nodes.

5) *The correlation between* actual PM10 values and test values came out to be 0.76 which is normal.

6) *While linear regression* is simple to implement but the values obtained were worst amongst all the models tested though better than ANN. It was fitted to reach the best accuracy of 76.42%, the least among all.

7) *The linear kernel* is shown to be the best input transformation technique for SVR.

8) *Stacking regressor performed* with mediocre accuracy among the others.

9) *For random forest*, the best results were obtained for 300 number of trees (accuracy 78.97 and RMSE 24.65), however, in comparison of all parameter values, Adaboost regression proved most efficient.

10) *Accuracy for Adaboost* reaches 98.24% which is highest among all the models as presented in Table IV.

11) *Thus, Adaboost Regression* was finally selected for Smog Prediction Model.

12) *Parameters such as correlation and RMSE* as shown in Fig. 9, 11, 12, 13, 14, 15 between measured and actual data for all models.

13) *As demonstrated*, multiple algorithms have been tested before determining the best and most efficient algorithm for Smog Prediction.

TABLE IV. COMPARISON OF MODELS

Model	Accuracy	RMSE	Correlation
Linear Regression	76.42	50.69	0.906964
ANN (MATLAB)	58.156	66.41	0.765523
SVR	80.9	33.28	0.914284
Random Forest Regressor (300 Trees)	78.97	24.65	0.917268
Adaboost Regression	98.24518	12.37	0.991843
Stacking Regression	88.18798	31.3603	0.942327

14)A differential factor not found in the previous research was that the models have been developed in a robust manner for which each model was re-built 25 times using different random subsets of training and testing samples keeping the splitting proportion constant.

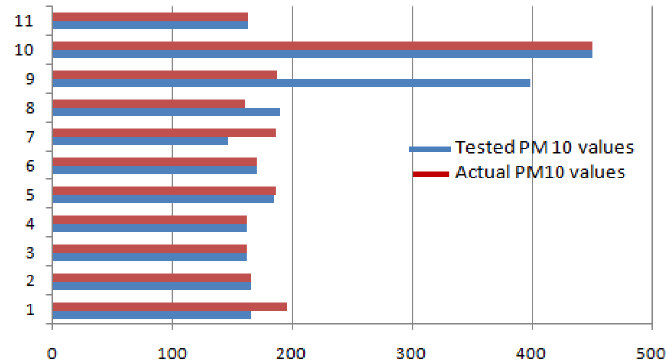

Fig. 9. ANN Correlation Data.

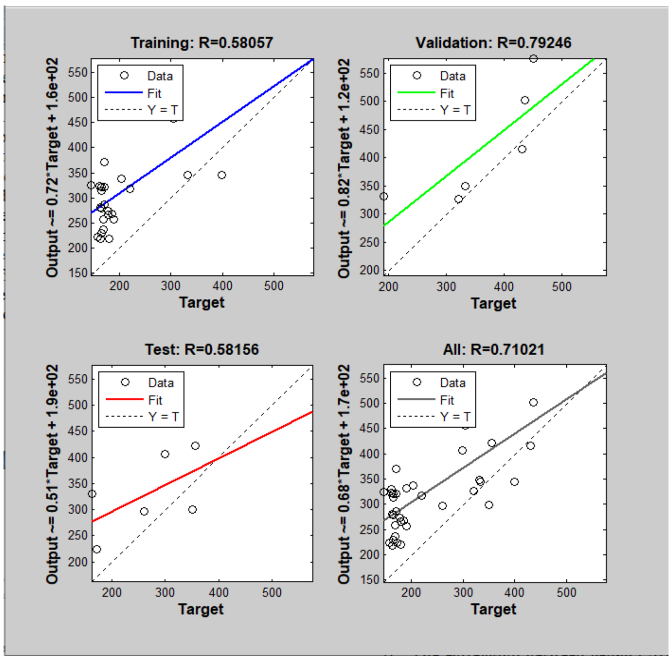

Fig. 10. ANN Accuracy.

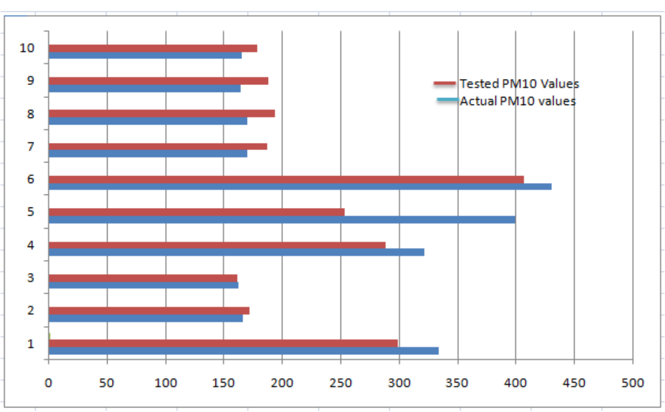

Fig. 11. Linear Regression Correlation.

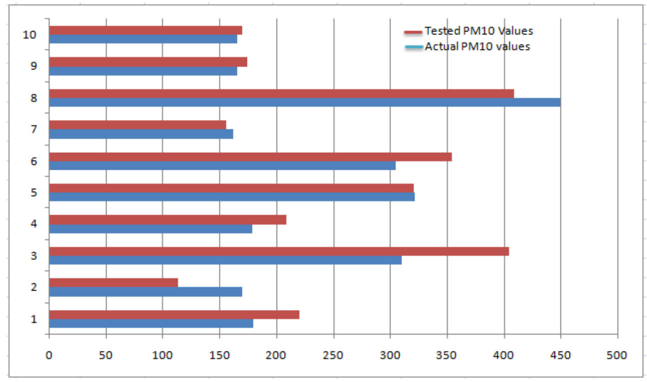

Fig. 12. SVR Correlation Data.

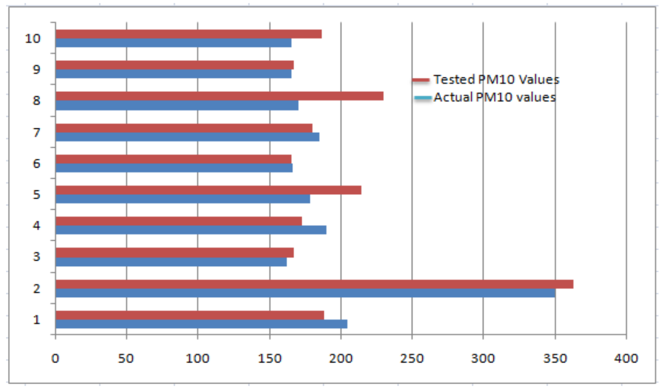

Fig. 13. Random Forest Correlation Data.

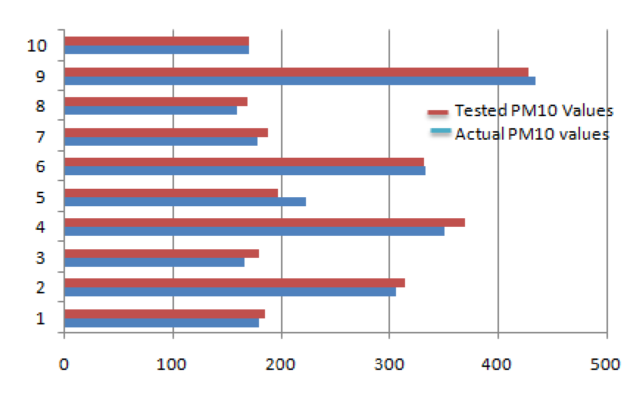

Fig. 14. AdaBoost Correlation Data.

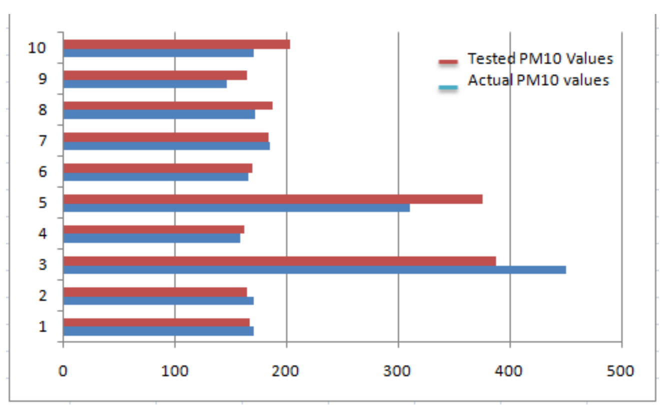

Fig. 15. Stacking Regression Correlation Data.

C. Magic Mirror

1) Fig. 17 shows the dynamic magic mirror screen output.

2) Fig. 16 shows the sensors output from Arduino and this output are taken as input to trained model for predicting smog.

3) Environmental conditions viz. sensors' output are displayed on the specially designed Magic Mirror/ Smart Mirror using Raspberry Pi and the same screen can be installed in the traffic vicinity or the traffic junctions in the metropolis/megalopolis for the common people to have 24 hours pollution and smog monitoring.

4) To make the demonstrated smart screen more attractive, additional features on the screen apart from air pollution data have also been incorporated like showing News, Calendar, and the Weather forecast of Delhi region as shown in Fig. 17.

5) Alert messages for maintaining social distancing and wearing mask for corona and air pollution has also been incorporated.

Fig. 16. Sensor Output on Magic Mirror Screen.

Fig. 17. Magic Mirror Display.

V. Discussion

The novelty of the system is the Smog Prediction model presented based on PM10 concentrations which is trained using Machine learning model. The system is based on constantly updated data and the finally displayed in a dynamic and interactive Smart Mirror. The machine learning model employed has been selected after extensive testing of six models with different parameters and the chosen model has the maximum efficiency and maximum stability. The dataset utilized is dynamic from both real time measurement as well as the internet.

The system presents an improved and calibrated approach towards data analysis by the sensor inputs and corrects PPM calculations thus making it accurate and ready to display in accordance with standard air quality index measurements. These values along with the obtained previous day PM10 values are fed as an input to the trained model to predict the formation of smog. Based on this analysis, SMS alerts can be sent by triggering communication with SIM800l using Python script when smog is detected to the designated traffic official to divert the traffic, especially at crowded junctions.

Thus, the system overcomes the limitations of the previous research by adopting sensor calibration, increasing number of sensors, varied datasets, improving accuracy of predictive modeling, presenting comprehensive comparative analysis of predictive modeling and implementing efficient use of resources.

The system is designed to be flexible and can be altered easily by adding new sensors. The system generates awareness among the masses and the government about air pollution and provides data to localized tackling of air pollution. A small compact kit can also be developed for indoor air pollution monitoring whereas for outdoors the entire kit would suffice for accurate results.

VI. Conclusion

The paper successfully implements a Smart IoT based Air pollution monitoring system that employs advanced machine learning models to implement a novel system with SMOG prediction modeling that helps in improving the health of the people and their environment by making them aware of their surroundings. The data is projected on a Dynamic smart screen/ Magic Mirror that can be displayed at various traffic junctions for general awareness. Also, the data and further graphical representations obtained can help the traffic department and environmental agencies to take corrective actions regarding the pollution levels as and when it is updated. This set up can further aid the local municipalities to take corrective steps and solve this rabid problem in a democratically decentralized manner.

An efficient, viable and affordable implementation of the system is presented that is functioning in real time conditions in New Delhi's environment. The System has been made flexible and to further hone the results of smog detection, ozone layer status sensor can also be utilized. PM 2.5 laser dust sensor can also be utilized; however, it may take up the cost of the system. For the purpose of forecasting air pollution on a large scale, large-scale node location and data collection can be expected in the future.

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Novel Secure Validation Scheme to Assess Device Legitimacy in Internet of Things

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***Abstract*—The increasing security concerns in Internet-of-Things (IoT) have led the researchers to evolve up with multiple levels of the research-based solution towards identifying and protecting the lethal threats. After reviewing the existing literature, it is found that existing approaches are highly specific toward stopping threats via predefined threat information. Hence, the proposed system introduces a new computational model capable of building up a flexible validation model for evaluating the legitimacy of the IoT nodes. The proposed system develops an algorithm that uses a simplified generation of secret keys, performs encryption, and generates validation tokens to ensure a higher degree of privacy and data integrity. The proposed model also contributes towards a unique energy allocation approach to ensure better energy conservation while performing security operations. The simulated study outcome shows better security and data transmission performance compared to the existing scheme.**

***Keywords*—Internet of things; security; validation; privacy; integrity; attacks**

I. Introduction

Internet of Things (IoT) offers more extensive coverage of different connected physical objects or machines, which are also known as things linked to a broader version of the network, i.e.,the internet [1]. Such physical objects are contributed by various technologies, software, hardware, actuators, and sensors, mainly with the objective of data transmission over the internet [2]. Data plays a significant role in IoT as this concept has evolved by integrating multiple technologies, e.g., automation, control system, wireless sensor network, ubiquitous computing, analytics, artificial intelligence [3]. This concept mainly targetsdeveloping a smart city by enabling more extensive connections of multiple and different types of machines. This causes a severe and increasing threat to security and privacy issues. There are various security concerns in the IoT environment connected explicitly with IoT devices and exchanged data. The first problem is its existing protection mechanism based on weaker password forms typically hard-coded and embedded within the device [4]. The second practical problem is associated with insufficient compliance of IoT devices manufacturers, which leads to insecure transfer and storage of data, usage of older operating environment and software, absence of robust updating mechanism, issues related to hardware, and hard-coded password. The next problem is related to a significantly lesser extent of awareness within the users, making the user morevulnerable in threat detection. Problems also exist due to the usage of insecure firmware. Due to this issue, the system suffers from brief downtime when the data is stored outside the cloud environment by the IoT device while performing updating operations. The existing physical devices are not secured from the external threat, which is not defined by the firewall system. Moreover, it is not feasible to imply a sophisticated security protocol running within the smart appliances or IoT devices due to their limitation of resource constraints and processing capability constraints. The usage of botnets by the attacker can significantly affect many IoT devices connected. Hence, during Distributed Denial-of-Service attacks in IoT, many connected appliances can be adversely affected. Apart from this, eavesdropping, industrial espionage, hijacking are some of the potential threats in IoT that have not yet met the robust security solution. There are various dedicated research-based solutions to deal with security concerns in IoT [5]-[9]. The conventional security solution of an IoT depends on Secure Socket Layer, Transport layer security, Datagram Transport Layer Solution, Quick UDP internet connection, secure MQTT, IP Sec [10].

Therefore, the research problem of proposed study is to address the limitation of conventional security scheme that may offer resistance but fails to offer full-proof validation of intention of any threat in large scale deployment over IoT. This problem is computationally challenging to implement whereas there is an increasing evolution of network devices as well as smart appliance for accessing services over IoT. Hence, this acts as motivating factor towards security for IoT devices.Therefore, this manuscript offers a solution to this issue by presenting a unique and lightweight validation scheme designed, unlike any existing approach. The prime objective of the proposed solution is to develop a computational framework that can perform secure validation towards securing all forms of IoT devices.The proposed model can identify the malicious intention of IoT nodes and offers a simplified encryption mechanism to mitigate the undefined threat in IoT. The paper also contributes to a novel energy computation scheme that compliments secure validation. The organization of the proposed paper is as follows: Section II discusses different taxonomies of existing security validation in IoT, followed by outlining research problems in Section III. Section IV discusses proposed research methodology while algorithm design is discussed in Section V. Section VI presents discussion while Result evaluation is illustrated in Section VII, while conclusive remarks are stated in Section VIII.

II. Related Work

At present, various schemes contribute towards security validation associated with identifying IoT devices while performing data forwarding.

- Blockchain-based Approaches: Blockchain is increasingly used in the majority of existing security approaches. The work presented by Hosen et al. [11] used context-aware blockchain validation. The approach also uses a software-defined network in the form of middleware to better control security operations in IoT. Banerjee et al. [12] have developed a blockchain-based authentication mechanism considering the key agreement protocol. The model is used in an implantable device that makes secure communication with the servers in the cloud. Blockchain is also reported to carry out authentication of cross-domain in IoT, as witnessed in the work of Ali et al. [13]. The researcher has presented a decentralized scheme for delegating permission and offer control over the structure of IoT. Further, the scheme also facilitates validating the local blockchain using the proof-of-Authentication and Integrity mechanism.

- Key Management-based Approaches: This is the most frequently used security scheme in IoT, where the emphasis is all about generation, storage, updating of secret keys among IoT devices. The computational model presented by Wang et al. [14] has presented a validation scheme for certificates used in IoT nodes. The prime idea is to assess the trust factor of IoT nodes. Xia et al. [15] have used a chaotic map to develop a key management scheme for authentication. The validation is carried out using informal security analysis along with the real-or-random model. Park et al. [16] have emphasized developing independent verification systems to offer untraceability and anonymity.

Further, the study has also used Burrows-Abadi-Needham logic to establish a secure bridge for mutual authentication servers and IoT devices. Shim et al. [17] have presented a study to assess a validation scheme towards anonymity issues in IoT. This security scheme is focused on the certificate's signature scheme to resist attacks towards secret keys and public keys. Another key-based protocol for validation is constructed by Saleem et al. [18], mainly targeting secure communication among cloud servers, roadside units, fog servers, and vehicles. Mahmood et al. [19] have developed key management based on distributed multiparty to carry out a compelling validation of nodes in IoT. The technique makes use of a chaotic map along with an on-way hashing approach for securing keying operation among all the core nodes and trusted servers. Public-key encryption and its different variant are witnessed to cover the IoT devices from most known threats. Such adoption of logic was reported in He and Zeadally [20],where elliptical curve encryption is used while validating RFID devices in IoT. The study outcome has found its security suitability on healthcare applications mainly. The work discussed by Yang et al. [21] has emphasized achieving forward secrecy in order to protect the session keys. For this purpose, a dynamic session key is presented,strengthening the credential management system in industrial-based IoTwithout any dependencies towards using primitives of public-key encryption.

- Policy-based Authentication:This scheme constructs a predefined policy to resist security threats. The security model of Banerjee et al. [22] has used a hashfunction with a defined security policy for offering validation for the regular/malicious IoT nodes. The study has also used a logical operator (bitwise exclusive OR) andan unclonable security function to compliment the device security. A similar approach of validation was also presented by Yanambaka et al. [23]. Existing studies have reported the usage of the message authentication scheme in order to construct a security policy in order to stop forgeability attacks in IoT. The model developed by Li et al. [24] has used identity-based encryption using signatures to strengthen privacy in IoT communication.

- Trust-based Security: These schemes are mainly meant for trust computation for ensuring the validation of IoT nodes. Rani et al. [25] have used game theory in order to evaluate trust in IoT. The work of Azad et al. [26] has used homomorphic encryption for securing the trust score in a decentralized manner. Xia et al. [27] have implemented a scheme for storage security using the trust factor to control accessibility. Almogren et al. [28] have used fuzzy logic for resisting Sybil attack and thereby developed a trust management scheme. The existing system has also witnessed other trust-related schemes by Truong et al.[29], Awan et al.[30], Fang et al.[31], Awan et al. [32], Wang et al. [33], Han et al. [34], etc.

- Unique Approaches: The work carried out by Amato et al. [35] has presented a unique technique based on workflow languages as well as semantics used for validating the inbuilt security characteristic of IoT devices. Another unique approach is presented by Ko etal. [36], where a validation scheme is designed using a tree that connects with variable security services with signature. The model assists the user in carrying out validation of the genuine sources anda relationship with the server. The existing system has also witnessed usinga cross-layer-based approach to offer an authentication scheme in IoT. The study carried out by Lee et al. [37] is mainly towards validation of user over physical layer as well as implementing encryption for large scale IoT deployment. The study makes use of the physical attributes in order to carry out preemptive-based authentication. Another unique approach witnessed in security validation in IoT is based on a group-based scheme, as witnessed in Aydin et al. [38]. The study has mainly targeted to resist man-in-middle attacks and replay attacks.The protocol also emphasized energy saving while carrying out group-based validation of many IoT nodes in a decentralized scheme.

The prominent research gap is existing approaches doesn’t offer lightweight encryption supportive of decentralized environment in IoTwith biased attacker identification policy. The next section outlines the problems associated with existing approaches and their methods towards validation.

III. Limitation / Research Problem

From the prior section, it has been seen that there are various approaches towards secure validation of an IoT device. After analyzing existing literature, apart from a valuable perspective in its security method and outcomes, there are also exploratory studies towards the limiting factors. This section outlines the limiting factors associated with the existing scheme as follows:

- Issues of decentralization: To offer more security coverage to large-scale IoT deployment, it is necessary to ensure the security scheme is decentralized. However, existing blockchain and key agreement-based schemes using a trust are more on a centralized security scheme and very much less towards decentralized implications. However, some work has used decentralized schemes, emphasizing delay control is not witnessed in existing schemes.

- Usage of Sophisticated Encryption: The encryption scheme is majority iterative and uses complex mathematical operations to ensure a better trapdoor function. However, the existing usage of encryption is quite voluminous, which will introduce a computational burden while trying to transmit data over the dense and more extensive network in IoT. Apart from this, sophisticated encryption will also saturate the resources to a higher level, and it is unlikely for the resource-constrained IoT nodes to sustain a more extended data transmission period.

- Unstructured Communication Scheme:The majority of existing secure data transmission scheme in IoT permits the data being captured from IoT nodes and directly forward to the gateway node. Such schemes offer higher resource fluctuation and challenge to control threats in case of multiple attackers in IoT. The impact of threat also becomes maximum. Such schemes cannot offer resistance from distributed denial of service attacks and man-in-middle attacks for large-scale deployment in IoT.

- Biased Identification Policies: Existing schemes are developed considering apriori information about attackers. Even the assessment is carried out using the same attackers. Such schemes will offer protection only from a predefined set of attackers and will never be able to identify if the attacker changes its strategy differing from what is coded within the firmware of the IoT nodes. A malicious node eventually does not attack when introduced in the environment; hence, existing security validation techniques will fail to identify dynamic attackers. The key management techniques are developed on an equal basis where there are fewer options for offering multi-stage encryption with a lightweight operation.

Apart from the above-stated problems, the existing scheme is not meant to cover up a set of integrated IoT attacks over a large scale. Apart from this, there is less consideration of resources used during validation during secure transmission. Therefore, the problem statement is "Developing a secure validation approach considering dynamic attack balancing with resource demands is challenging computational task in IoT." The next section outlines the solution towards this problem.

IV. Research Methodology

The proposed methodology addresses the limitation of existing approaches presented in prior section. The issues of decentralization is solved by presenting a lightweight encryption operation supportive of decentralized environment in IoT. The limitation of usage of sophisticated encryption is solved by parallel assessment of energy along with generation of secret key. The problem of unstructured communication scheme is addressed by developing a specific topology of an IoT which organization device and its respective communication with a gateway node. The problem of biased identification policies is addressed by performing secure modelling of local and global IoT. Local IoT would mean a network with a single application, while global IoT would mean forming a centralized network with multiple (and diverse) applications. Therefore, the proposed system uses a domain-based communication system where the domain will refer to a particular local IoT device where a heterogeneous domain performs its communication via a gateway node. Initially, simple modelling is being carried out by defining actors in local IoT (datacenter, target IoT, sensors) and global IoT (network of all the datacenters). A novel authentication mechanism is presented among all the possible actorsresiding within the local and global IoT domain by incorporating challenge and response-based approaches. A sophisticated validation module will be designed to validate the legitimacy of the requestor node. The research methodology adopted is analytical-based, as shown in Fig. 1.

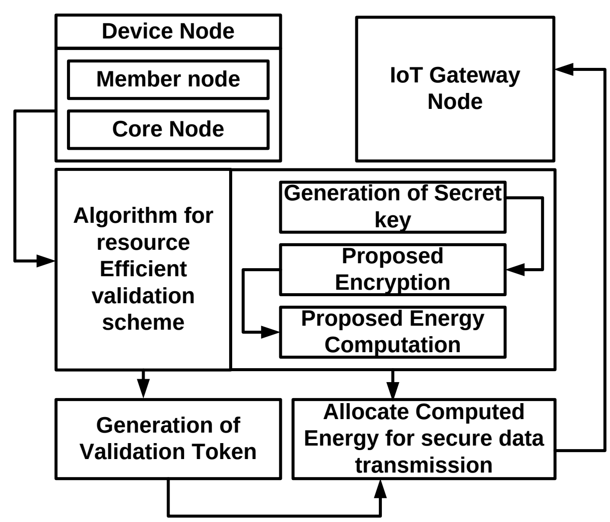

Fig. 1. Tentative Research Methodologies for Phase-II.

The proposed system will formulate an algorithm for ensuring both forward and backward secrecy to safeguard the presented authentication framework for any possible threats. The system will use cipher-text-based encryption and novel energy computation to strengthen the authentication mechanism with lower resource consumption. The novelty of this model is its validation process which is meant to mitigate dynamic threats in large-scale IoT more effectively and in a decentralized manner to offer more security coverage. The next section discusses algorithm design and implementation towards the model.

V. Algorithm Design

The primary concern of the proposed system is to construct a unique validation scheme that could be used for assessing the authenticity of the IoT nodes. Owing to the last deployment scenario in an IoT, it is required to ensure that this scheme should also be resourced efficiently, balancing with the security demands. The proposed algorithm performs this dual-task in combining the security features with resource efficiency features. The steps of the proposed algorithm are as follows:

Algorithm for Resource-Efficient Validation Scheme

Input: n, A, s, e, p
Output: v_{tok}, E
Start
1. init n, A, s, e, p
2. **For** i=1:n
3. $n_{mem} \leftarrow$ msk
4. $[d, e, n] \leftarrow f_1(\text{msk}, \text{NP})$
5. $n_{core}=A_{ix}(G_i(r<T_i))$
6. $[v, ix] \leftarrow \arg_{min}(\text{dist})$
7. $[v_{tok}] \leftarrow f_2(\text{msg}, enc_i, n_i)$
8. $E_{tx}=f_3(\text{dist}, \text{PL*cm})$
9. $E(n_{core}(i)] \leftarrow E(n_{core}(i))-E_{tx}$
10. **End**

End

The algorithm takes the input of n (IoT nodes), A (simulation area), s (gateway node), e (initialized Energy), p (probability of core IoT node) that upon processing yields and outcome of v_{tok} (generation of validation token) and E (computed Energy). The proposed algorithm initializes a master key *msk* and allocates it to a structured memory system n_{mem} of a node (Line-3). The next essential step of the proposed algorithm is to apply a customized function f_1(x), responsible for carrying out a secret key generation. The internal steps of f_1(x) are as follows: The function takes the input of master key *msk*, and nearest prime number *NP* and it generates three attributes memory structure of decryption *d*, memory structure of encryption *e*, and IoT nodes *n* (Line-4). Following are further steps:

- The IoT nodes *n* is computed by-product of master key *msk* and nearest prime number *NP*.
- An internal security attribute is constructed Φ, computed as Φ=(msk-1)(NP-1).
- The greatest common divisor is computed concerning random numbers for *NP* and obtained internal security attribute Φ.
- The value of this scheme is obtained by applying the modulus of the product of *d* and *e* and Φ.

The obtained information of attributes *d*, *e*, and *n* are further updated in the memory systems, accessed by legitimate IoT devices on a memory-sharing basis. In order to offer better control of the communication in large-scale IoT device deployment, the proposed system introduces a threshold-based provisioning scheme for the selection of core IoT nodes n_{core}(Line-5). The proposed mathematical expression of this threshold is as follow:

$$T = \frac{p}{\Delta p}.\Delta E \quad (1)$$

In the above expression (1), three dependable parameters are used in computation, i.e., p, Δp, and ΔE. The first variable,*p*, represents the probability that one of the IoT devices will be provisioned as a core IoT node authorized to forward the data to the gateway node. The second variable Δp represents $(1-p(|1/p|)).E/E_{init}$, where E and E_{init} represent total and initialized Energy, respectively. The selection of core IoT node n_{core} is selected considering matrix A_{ix} which retains all active nodes with E more than zero and any candidate IoT node randomly selected number less than T_i (Line-5). It should be noted that the variables T and T_i are different as the former is represented by mathematical expression (1) while the latter is represented as $T_i=E(G_i)$. It will mean that T_i is the threshold considered for all the randomly selected candidate nodes G_i which has sufficient residual Energy. The next task is to compute the distance *dist* between all the candidate IoT devices with the core IoT device (Line-6). The proposed system computes the minimum distance and obtains its value *v* and coordinates *ix* (Line-6). The variable *ix* is further used for updating the core IoT device. The next part of the algorithmic step is to perform encryption using an explicit function f_2(x). Following are the internal operation of this encryption function:

- The function f_2(x) takes the input of message *msg*, encryption attribute enc_i, and IoT device $n_{i,}$ which yields an outcome of validation token v_{tok} (Line-7).
- The first step is to compare the length of the message *msg* with the unit value. If it is found more than the unit value, then the size of the message is reduced to 32 bit.
- A simplified encoding is carried out for the encrypted attributed enc_i by converting decimal to binarized value.
- The function further compares the value of obtained encoded value from the prior step with the unit value. If the size of the encoded value is found more than the unit value, then it further put forward a condition where the value of the encoded attribute is equated to the unit value. The coefficient c is computed as,

$$c = |(c^2, n) * msg, n|, \text{ c=1} \quad (2)$$

$$c = |(c^2, n)| \quad (3)$$

The expression (2) is implemented if the encoded value is equal to the unit value, while expression (3) is implemented if the encoded value equals zero. The outcome, by either condition, generates coefficient c, which is a validation token vtok (Line-7). This completes the operation of the proposed encryption.After the encryption is carried out, the next emphasis is given to control the energy dissipation. The proposed system implements the final function f_3(x), which mainly targets to reduce the dissipated Energy while forwarded the encrypted data from the core IoT nodes to the gateway node (Line-8). Following are the internal steps being carried out towards energy control function f_3(x):

- This function takes the input of distance *dist*, length of data *PL*, and domain member *cm*. The proposed system considers domain-based communication where the domain represents a group of similar IoT devices. Each domain consists of two categories of nodes, i.e., domain member *cm* and core node n_{core}. The elementary information is captured by domain member *cm* and is then routed to core node n_{core} while the core node n_{core} forwards all the data collected to the gateway node. The proposed model implements a standard energy computation of hierarchical communication scheme [39] for computing transmittance energy.
- The energy model used in this part of the implementation emphasizes the distance attribute. The core idea is to ensure that the distance between two communicating nodes is kept as minimal as possible. A higher distance will eventually lead to excessive energy drainage. Hence, a greedy approach is applied to ensure that nodes with minimum distance criteria perform data transmission to the gateway node.
- While performing the energy computation, the energy control function f_3(x) considers practical energy factors, e.g.,Energy required for antenna to carry out transmission within an IoT device, Energy required to amplify the signal, length of data to be transmitted, and distance. Further, the function initializes the Energy required to transmit validation token v_{tok}. This operation can be carried out for both active and passive modes of validation.
- The active mode of validation is when the validation is required instantaneously by the user, while the passive mode of validation is when the validation of the security token can be done later. The difference is that an active mode of validation is carried out before the data is transmitted, while a passive mode of validation is carried out when the data starts receiving at different network elements in an IoT environment. The active mode of validation can be carried out in case of a known attack, while the passive validation model can be carried out if the attacker strategy is unknown to the user. In both cases, safety is ensured. Therefore, the total energy consumption will bea summation of Energy required in performing either mode of validation of v_{tok}.

After the cumulative energy E is computed, the proposed system performs a reduction of Energy. This is carried out by obtaining the appropriate Energy obtained by subtracting the total Energy of the core IoT device with allocated transmitted Energy (Line-9). Unlike any existing energy modelling, the novelty factor is thatthe proposed system does not allocate static Energy, but it computes the exact necessary Energy and allocates it after performing the encryption steps. The next section discusses the discussion followed by results evaluation.

VI. Discussion

At present, there are scattered and multi-variants forms of security approaches to ensure that accessibility towards the IoT device is always carried out in secured manner. There are reported claims of benefits observed in existing approaches too in this regards on the basis of reviews carried out in Section II. However, a closer look into the review of literature shows that there is no potential connectivity among the existing techniques, which will mean that hybridization of multiple techniques are extremely challenging with existing approaches. The prime reason behind this is the dependencies of research environment, specification of implementation, and applicability are highly narrowed scope. Hence, there is no scope of integrating conventional security approaches towards assessing the legitimacy of the devices. This calls for evolution of the novel idea presented in this paper, where the idea is to address the identified research problem / limitation outlined in Section III.

A closer look into existing approaches shows that they are yet not much supportive of decentralized environment. This problem is directly addressed by implementing a key generation approach discussed in Section V considering completely distributed communication among IoT nodes in the form of cluster. Unlike any conventional IoT system, where there are only two roles of nodes i.e. IoT node and IoT gateway node, the proposed system offers two more distinct roles i.e. member node and core node, which is designed from the operational features of sensor network in IoT environment. The benefit of this scheme will be i) highly supported of decentralized environment considering local and global IoT system, ii) highly structured communication among different roles of device nodes and IoT gateway node, iii) conservation of energy due to structured communication system. Apart from this, the security strength of proposed system is further leveraged by inclusion of validation token which ensures the legitimacy of the node to participate in data communication process.Another interesting contribution of proposed methodology that separates it from existing approaches are its formulation of validation technique and all its attributes involved in it. Majority of the attributes used in the formulation of algorithm discussed in Section V i.e. distance, nodes, master key, message, encryption attribute, etc. are readily available from neighborhood node or hop table. No extensive computation is required to assess the validation token except few conditional checks being carried out. This significant reduces the computational burden and make the system highly scalable in peak traffic load in IoT for secure validation. Result evaluation is discussed next.

VII. Evaluation

This section illustrates the outcome obtained by implementing the secured validation in IoT. It is to be noted that the proposed system introduces a flexible validation scheme contributing towards secure communication in IoT.

A. Simulation Parameters

The proposed system is scripted in MATLAB on a regular 64-bit machine with a Core i5 processor. The study is evaluated considering 100-500 IoT devices deployed in an arbitrary position in a simulation area of 1000 x 1000 m^2 considering the variable location of the gateway node. The initialized Energy of IoT nodes is considered 10 Joule with a 5% probability score for a member IoT node to become the core access node in IoT. The proposed study also consider variable energy attributes, e.g., theEnergy utilized for data transmission by IoT nodes as 5nj/bits, Energy required to amplify signals by wireless IoT nodes as 100 pJ/bit for every squared meter of simulation area,Energy utilized for generating and assessing validation token as 80 μJ/validation tokens, Energy required for assessing validation token in active mode as 13μJ/validation tokens, Energy required for assessing validation token in passive mode as 5μJ/validation tokens, the size of the data packet is 1000 bytes. The consideration of the values has been considered according to the standard ranges observed from existing literature and standard secured hierarchical protocols.

B. Simulation Environment

The first step of the implementation is to deploy a generalized IoT environment consisting of member IoT devices, core IoT devices, and a gateway node. A domain-specific communication is carried out where the member IoT nodes forward the data to core IoT nodes which further aggregates the data and forward it to either gateway node directly or forward to its nearest neighboring core node. The direct transmission to the gateway node is carried out if the distance between the core node and gateway resides in the proximity of each other. Otherwise, multi-hop transmission is carried out via other core nodes to the gateway node. Assuming the presence of attackers, the analysis is carried out as the proposed system is designed to resist any form of key-based and routing intrusion associated with identity-based theft attacks in the IoT environment. The communication is permitted to continue for 7000 simulation rounds till all the IoT nodes are depleted of their Energy.

C. Performance Evaluation

For an effective benchmarking system, the proposed system consider the existing system of the secured hierarchical protocol [39], which acts as baseline security of IoT device. The prime justification of adopting this existing system for benchmarking is as follows: i) sensors and actuators are an integral part of an IoT environment in the form of IoT devices compliant with security protocols applied for sensory application. Hence, secure hierarchical protocols [39] offer a balance between security and energy efficiency, which suits the proposed objectives too, ii) it offers a standard mathematical formulation to compute Energy considering various energyattributes. In order to facilitate equivalent testbeds, similar energy parameters are also selected to carry out the proposed implementation. This will offer a fair outcome in a similar test environment for both proposed and existing systems. For more granular analysis, the proposed system is assessed for both its active and passive state of verification of validation tokens. The performance parameters selected for the analysis are rounds required to complete validation, number of sustained nodes, delay, throughput, resource, fluctuation, and overall energy depletion.

D. Impact of the Proposed System on Transmission

This section discusses the simulation outcome involved for each performance parameter.

1) Validation round: The first performance parameter to assess is validation rounds, computed by observing the total number of rounds required for both proposed and existing systems to complete the validation.

Fig. 2 highlights the simulated outcome of observed validation rounds where the proposed system is observed to found lesser validation rounds thanthe existing system. The proposed system with passive state *Prop(P)* is found to occupy less validation time than that of active state *Prop(A)*. The prime reason behind this validation inactive state includes end-to-end node validation, which is not in the case of the passive state. On the other hand, existing Secured Hierarchical protocol *Exist(SecHier)* carry out iterative validation till all the IoT node depletes its complete Energy. Hence, the existing approach is found to offer more validation time compared to the existing system.

2) Number of sustained nodes: Basically, sustained nodes will mean the number of IoT devices found to possess specific cut-off Energy. A sample analysis has been carried out for 100 IoT devices, and the outcome is found to be precisely similar even if the number of nodes is increased. While the simulation is carried out, observed values for several nodes with optimal residual Energy are obtained to achieve the graphical outcome stated in Fig. 3.

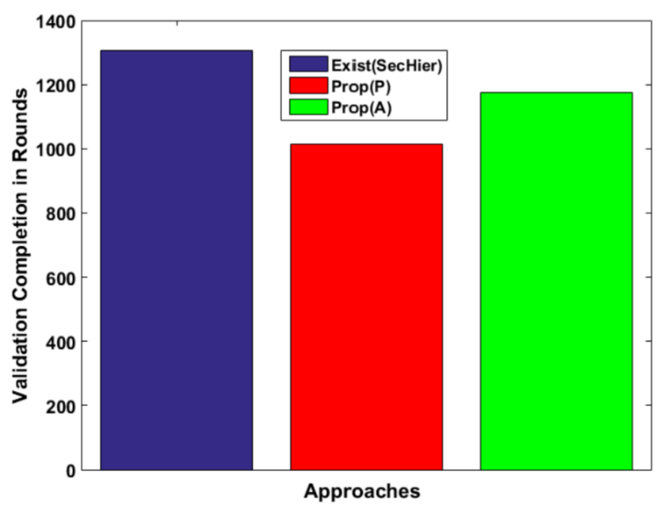

Fig. 2. Comparative Analysis of Validation Rounds.

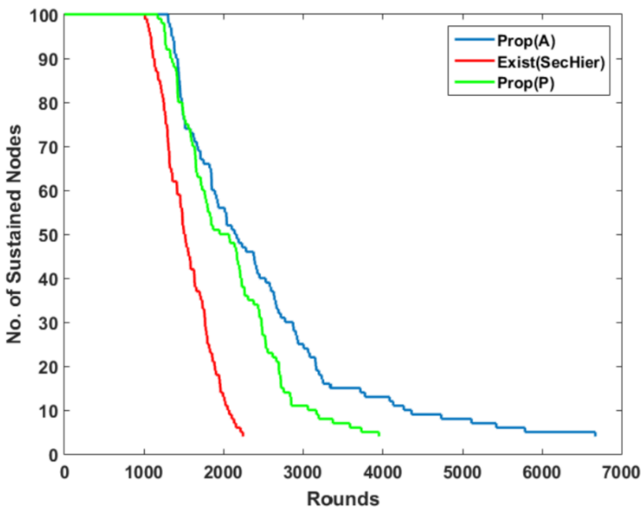

Fig. 3. Comparative Analysis of Number of Sustained Node.

According to the trend of curves in Fig. 3, both the version of the proposed system offers more sustained nodes for increasing rounds of simulation in contrast to the existing scheme. The existing scheme lets all the IoT devices perform secured data transmission using a conventional public encryption scheme. This will demand more memory dependencies toward each IoT node, which results in a more saturated state of a gradually increasing number of IoT devices, which results in faster drainage of Energy; hence, existing system collapse even before completion of 50% of simulation rounds. On the other hand, the proposed scheme with a passive state offers more sustainability, but due to not considering end-to-end node validation, each node must be finalized 100% of validation. However, the proposed scheme with active mode has a memory sharing feature that lets all nodes perform 100% of validation simultaneously compared to an existing system with a passive state. Hence, the passive state is ideal for medium-scale deployment, while the active scale is ideal for large-scale deployment of IoT.

3) Delay: The proposed system considers end-to-end delay, which is consumed time for transmitting the packet from transmitting IoT device in one domain to the gateway node inclusive of all the relay nodes within it. Delay is one of the essential parameters to judge the possibility of various attacks (e.g., flooding-type attacks, man-in-middle attacks). Delay is an eventual part of large-scale IoT communicationdue to various intrinsic and extrinsic factors in IoT. The intrinsic factors will be the data packet size, the number of available IoT devices, the distance between two transmission points, and the job saturation state of each relay node. The extrinsic factor will be interference caused by communication, densityof IoT nodes, battery life of each node, queuing process adopted, etc. An effective security logic should optimize the delay performance so that with an effective delay score, the transmission of the packet could be carried out securely and for the more extended extensible period of data transmission between IoT nodes and gateway nodes.

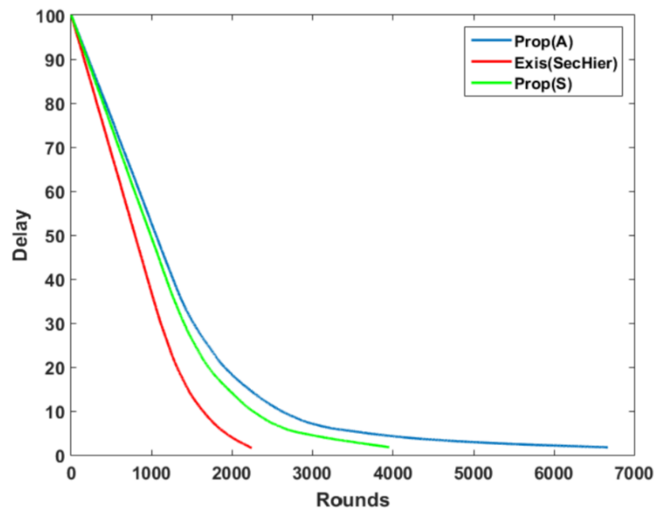

Fig. 4. Comparative Analysis of Delay.

Fig. 4 highlights the simulated outcome of delay. A closer look into this outcome will show that the proposed system offers extensible delay performance, which permits data transmission till maximum simulation rounds, unlike existing approaches. The justification of this outcome is similar to that of the number of sustainable nodes.

4) Throughput: This performance parameter is computed as the number of arrived packets from transmitting nodes to the actual destination node with the inclusion of all relay nodes. An effective security protocol should offer better throughput performance to ensure that its security scheme does not hamper the data transmission performance.

Fig. 5 exhibits that the proposed system offers better throughput performance compared to the existing scheme. The prime reason is that the existing scheme doesn't offer sustainable nodes to carry out data transmission, whereas the proposed scheme offers more sustainable nodes, resulting in better throughput performance. The idea is to balance Energy, data transmission, and internal security operation at the same time.

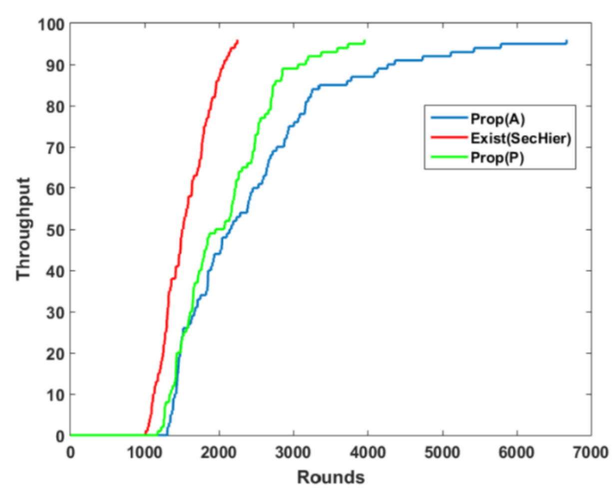

Fig. 5. Comparative Analysis of Throughput.

5) Resource fluctuation: An efficient security protocol should offer consistent resource utilization to retain more IoT nodes to carry out secure transmission.

However, resource demands can fluctuate depending on the random allocation of the data packet and the different dynamics present within the IoT environment. The standard variance parameter computes this parameter in statistics associated with transmittance energy. Fig. 6 highlights that the proposed system offers slightly more resource fluctuation (5-10%) thanthe existing approach. The contribution of this scheme is that although it offers little more resource fluctuation, it still manages to use maximum IoT nodes till the end of the simulation, whereas the existing scheme fails to do so. Hence, although the existing scheme offers lesser resource fluctuation, it can still not be deployed over a large-scale application in IoT.

6) Energy depletion: The proposed system makes use of expression used in its algorithm to compute the Energy. The outcome of Fig. 7 highlights better energy retention of the proposed system over more simulation rounds.

E. Impact of Proposed System on Security

The proposed algorithm offers a significant level of security in IoT. The lightweight cryptographic operation carried out in the proposed system offers better confidentiality as well as data integrity. On the other hand, the usage of validation tokens can ensure the better form of non-repudiation and authenticity factor associated with transmission in large-scale deployment in IoT. The security analysis towards different variants of attacks in IoT are briefed as follows:

- Resilience towards passive form of intrusion: The encryption method used in the proposed system benefits the system due to performing computation over a ciphered packet with non-dependencies towards performing initial decryption. This operation result leads to encrypted data, which, when subjected to decryption, will lead to a unique identical outcome. Hence, it can be used to preserve privacy for the computation and outsourced storage in the data center. The significant beneficial factor of the proposed system is that IoT nodes perform encryption and forward the data to a gateway that further forwards it to the datacenter, encrypting it. Therefore, any form of the passive intruder will notcompromise the transmitted data without possessing the decrypted key, which is further computed and not stored in any device.

- Resilience towards active form of intrusion: In most such attacks, the target victim will be the core IoT node as the relay node due to the restricted operation by the member IoT devices in a domain-based communication system. As the intruder will not have possession of a legitimate validation token in order to perform concatenation with the beacon to be broadcasted in a wireless environment by IoT nodes, it will be impossible for an intruder to act as a gateway node or even the core IoT node in order to launch an attack. Hence, any possibility of identity-based theft is not possible by an attacker while it offers higher resistance towards selective forwarding attack and sinkhole attack in IoT, which the existing protocols cannot stop. Further, along with the usage of validation tokens and memory sharing among the IoT nodes, the proposed system also offers protection against flooding attacks.

- Resilience to device compromise intrusion: In case of device compromise intrusion, the victim IoT device acts usually but will carry out malicious intention towards each transmission and data processing activity. Assuming that a victim node acts as a member node or relay node, there are still requirements under a validation check by generating a secret key. It is unlikely that the victim node will generate the secret key obeying the proposed protocol, and hence the secret key generation before encryption by the victim node will eventually fail to comply. This will itself stop all communication with the victim node and updatethe trust value of the victim node. Hence, even if the victim node is present inside the network, they will never participate in any data processing or data transmission in IoT. Dependency on multiple parameters will also stop the victim node from carrying out this computation.

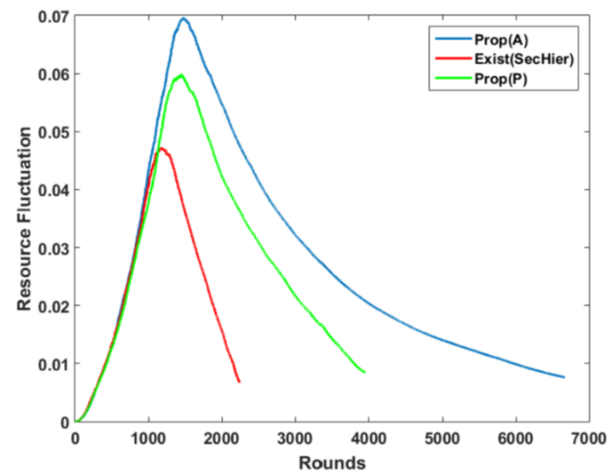

Fig. 6. Comparative Analysis of Resource Fluctuation.

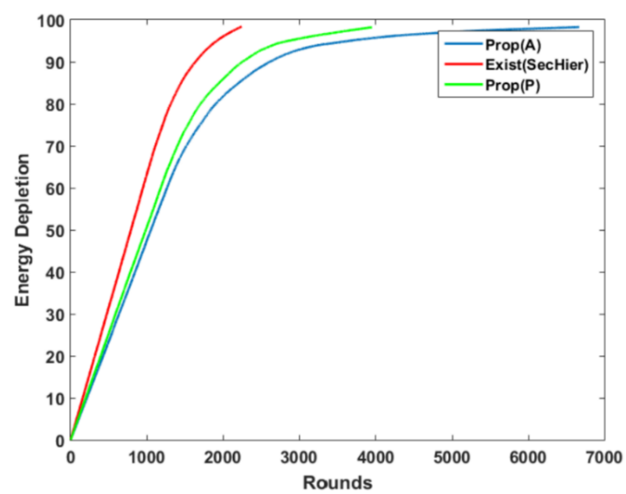

Fig. 7. Comparative Analysis of Energy Depletion.

VIII. Conclusion

IoT security has been a critical concern forthe past few years, which has not yet met with an effective solution. The existing solution is based on predefined knowledge of the attacker to circumvent the defined threats. Such a scheme is not capable to even identify the attacker when they alter their strategy. Hence, this paper offers a solution by presenting a secure validation technique thatidentifies the malicious intention of an IoT device and protects the data. It should be noted that proposed system is assessed over a formulated IoT environment scripted in MATLAB where data packets are programmatically generated based on arbitrary traffic load in order to map with practical world use-cases. Hence, the proposed system is applicable for any form of data or traffic environment over IoT, which increases the scope of implementation. This is one significant novelty factor unlike existing systems which mainly uses data traces. Apart from this, another novelty of proposed system is introduction of roles of IoT device to understand the demands of security and communication system over decentralized environment unlike existing approaches. The inclusion of local and global IoT will also contribute to novelty factor of proposed system.

Following are the contribution/novelty of the proposed system, viz.

- The proposed system introduces a secure validation that is capable of performing in both active and passive states of communication in IoT.
- The proposed system performs validation of the encrypted data by applying validation token along with the packets, further followed by secret keys in order to offer more layers of security.
- The proposed system does not make use of any complex or sophisticated encryption operation, and hence it is capable of conserving maximized sustainable IoT devices for a longer time.
- A unique energy computation is carried out in proposed system which ensures allocated of appropriate Energy required for transmitting encrypted data to the gateway node, unlike any existing techniques where static Energy is allocated every time in data transmission.

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An Efficient IoT-based Smart Water Meter System of Smart City Environment

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***Abstract*—Water is a precious need of our lives. Due to the rapid population and urbanization, water usage monitoring is a significant problem facing our society. One solution is to control, analyze, and reduce the water consumption of the houses. The emerging of the Internet of Things (IoT) concept lately in our lives has offered the opportunity to establish water usage-efficient smart devices, systems and applications for buildings and cities. Many studies have suggested designing an IoT-based smart meter system; however, the IoT sensor node has limited studies, especially in battery life. Therefore, this study aims to implement and analyze an efficient data collection algorithm for IoT-based smart metering applications in consideration with energy consumption. The system items used are Arduino Uno, Wi-Fi-ESP8266, and water flow sensors. The applied algorithm is an efficient data collection algorithm for water meter (EDCDWM) to reduce the number of packet transmissions. Arduino performed this system's implementation, while the simulation and analysis performed by MATLAB R2019b. The average percentage of energy saved by the applied algorithms of EDCDWM absolute change; and EDCDWM with relative differences in all nodes are around 60% and 93%, respectively.**

Keywords—Internet of things; smart water metering; energy consumption; smart city

I. Introduction

In many countries, water conservation is becoming increasingly necessary as countries face a widening gap between the ever-decreasing water availability due to climate change and the rising demand for population growth. Water efficiency implies less water consumption and searching for an alternative of conventional water meters to measure the quantity and quality of water. Water utilities build daily demand profiles and peaking factors to construct water delivery network infrastructure [1]. The role of smart metering is increasingly recognized by water utilities in demand management, customer service, work optimization and operating efficiency [2]. Today's advanced programs include water-efficient sensors and innovations such as the Internet of Things (IoT) based smart meters are increasingly highlighted [3]. There are significant advances in optimizing water-intensive processes and controlling activities where automatic leak detection and monitoring systems permit to locate and cut off the leaks flow automatically and even patch the leaks [4].

IoT is defined as a system where physical objects can become active participants, and resources can be accessed over the internet through the cloud to communicate with these objects [5][6]. It allows devices and networks to connect, share and store data with or without human interference on the cloud platform using the internet. To send data from a device to a cloud, it is required to add a new device on the cloud and get the device credentials which are the username and device ID. These credentials are used to set-up a connection between Wi-Fi and the cloud to send data to the cloud. After identifying the Wi-Fi in the cloud, it can receive the transmitted data by the Wi-Fi. The smart meter water usage offers a solution to overcome water consumption issues and monitors the amount of water used by each household or building to control their consumption level. Random consumption problems should be avoided when installing this smart water meter [7][8], and the water consumed can be monitored using the internet. The water supply may be terminated if people are not present in their homes, and water usage is decreased directly or indirectly [9].

This study presents an analysis and implementation of a smart water meter that uses an embedded device. Arduino microcontroller and Wi-Fi are used to introduce the 'Smart' feature in a traditional domestic water meter. The IoT-based smart water meter built in this research allows reading the meter without physically entering each house periodically. This was accomplished using the Arduino unit, which continuously monitors and records the water flow sensor's readings in its memory. The meter is connected to the internet using Wi-Fi, making the device part of the IoT. The user and

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the service provider would be able to display and read the consumed water along using this smart water meter. Via such a comprehensive record of events, the service provider can keep track of the trend of water use, allowing better and efficient forecasting and management of use. On the other hand, the payment system will become more transparent for clients.

The rest of the paper is organized as follows: Section II presents the motivation of this study and the main contributions. The related works are presented in Section III. Section IV describes the system design of our proposed approach. The proposed algorithm, experimental results and simulation are explained in Section V. Finally, Section VI presents the conclusion of the paper.

II. Motivation

As a result of rapid population and urbanization, water demand is rising for various purposes such as agriculture, industries, homes, hospitals, etc. Furthermore, the world is looking forward increasingly to adapting and introducing modern technology to enhance the quality of life and reduce the impact on the environment of human activities and patterns of consumption. However, rapid changes in lifestyle and increased paying capacity have had an effect on the usage of water and associated overheads on sewerage requirements [10][11]. Hence there is an urgent need to conserve as much water as possible with the integration of technology. Therefore, water usage-efficient operation requires water usage analysis constructively based on data collected from many applications. This study involves collecting sufficient analytical data, which requires the acquisition and transfer of data from multiple sources in real-time, high processing power and storage of massive data sets. The current system provides a unique twist to the smart water meters using IoT technology, where the smart meter data is stored in the cloud. Nevertheless, the IoT sensor node has limited resources, especially in battery life. Therefore, this project aims to reduce the energy consumption during the data sending process to the cloud, extending the sensor's node battery lifetime by implementing and analyzing an efficient data collection algorithm for IoT-based smart water metering application.

For a more high-efficient operation of water-usage, we have designed a smart water meter using IoT technology. As IoT-based devices have limited power resources and rely on batteries, therefore we proposed an efficient data collection algorithm to reduce the data transmission and thus we can extend the battery life. For evaluation, the developed system has been tested in many scenarios.

The main contributions of this research are as follows:

- Design an IoT-based smart water meter system.
- Implement an efficient data collection algorithm for IoT based smart water metering applications.
- Evaluate the performance of the data collection algorithm in terms of energy savings and the amount of data transmission.

III. Related Work

Many researchers have investigated smart water meters systems for efficient control of water in the built environment (Table I). In [12], the authors suggested an integrated (IoT) infrastructure for smart meter networks in smart cities. The proposed design used communication protocol, data format, data collection procedures, and decision system based on big data processing. Furthermore, in [13] the authors suggested a method to reduce the number of transmitted packets in order to extend the sensor’s node battery lifetime. So, the suggested method supports single and multiple sensors. In [14], the authors designed and implemented an innovative smart energy meter based on the internet of things. This system uses the IoT power meter, installed at the top of the traditional consumer power meter, which provides detailed electrical energy use information. Moreover, in [15] the authors studied various algorithms' performance, which reduces the number of transmitted packets through Wireless Sensor Network (WSN) by the nodes attached to it. The algorithms were tested by applying them to data from temperature, relative humidity, and light sensors. The data produced by these three types of sensors were collected by Intel Berkeley Research Laboratory (IBRL). In [16], the authors proposed a power dissipation model to determine fault detection cost at the edge device level. The proposed model was used to assess the impact of various data validation schemes on the power consumption of edge devices. The analysis revealed that defining a data validation scheme at the edge device level was a critical issue. In [17], the authors designed a smart energy meter platform and their system implemented and built included clouds, smart plugs, and gateways. The system was applied in industrial centers and buildings to sense energy consumption and the power system's parameters. Furthermore, [18] proposed implementing a smart energy meter with a very low-cost wireless sensor network and web application protocol that can read the units and send the measured data to users automatically to display their current reading of a smart energy meter. The system consists of a digital energy meter, ESP8266 Wi-Fi module, and web applications for the management system. In [19], the authors proposed a system that monitors energy consumption using the IoT. The system consists of an Arduino Uno board as a microcontroller that communicates through Ethernet using the IP address on their computers to receive information about energy usage. In [20], the proposed system designed by authors was able to read the water consumption and send the consumption to customers. The water meter's primary function is to secure, regulate, and track water supply. The system was designed from Microcontroller (ATmega328), GSM Module (SIM800), LCD Module (1602A), and Step-down Transformer. In [21], the authors proposed mobile applications using low-cost IoT hardware for smart metering.

TABLE I. SUMMARY OF THE RELATED WORK

Ref.	Application	Implementation	Sensor	Architecture	Update data strategy	Energy Consumption Analysis
[12]	Energy, Water, Gas	Simulation Spark SQL as a database system	Electricity, water, Gas	IoT	No	Yes
[13]	Environment	Simulation MATLAB	Humidity, Temperature, Atmosphere Pressure, Carbon Dioxide, Libelium Gas	IoT/WSN	Aggregation, EDCD algorithms	Yes
[14]	Energy	Prototype Serial port, opto-coupler MCT2E	Current	IoT	No	No
[15]	Environment	Simulation MATLAB	Temperature, Relative Humidity, Light	WSN	AR-B, MA, AR-YW, EDCD1	Yes
[16]	Environment	Simulation MATLAB	Current, VSNL	IoT/WSN	ER-NN, ER-HD, ED-NN	Yes
[17]	Energy	Prototype Arduino Uno	Current, voltage	IoT	No	No
[18]	Energy	Prototype ADSL modem	Power, Temperature, Humidity, Brightness, Gas leakage	IoT	No	No
[19]	Energy	Prototype Arduino Uno	Current	IoT	No	No
[20]	Water	Prototype Microcontroller (ATmega328),Proteus	Flow Sensor (Hall-Effect)	GSM	No	No
[21]	Water	Prototype Arduino SBC, Ethernet Stack,Flash Memory,LCD	Tamper-flag	IoT	No	No
[22]	Water	Prototype NodeMCU	YF-S201 water flow sensor	IoT	Yes	No
[16]	Water	Prototype LinkIt ONE development board	ultrasonic flow sensor, PT1000 temperature sensors	MCS, IoT	Yes	No

The system allowed both the Meter Reader and individual domestic/industrial customers to use standard smartphones to read and update meters to the utility's billing and payment portal/database. The proposed Smart Meter System was composed of the Electronic Interface Module (EIM) hardware component, which resides in conjunction with the basic water meter. In [22], the authors designed a smart water metering that curbed water pollution. The proposed system has been used combined with machine learning-based tools to identify excess water consumption with simple monitoring and visualization of the data via the cloud platform, where the system adopted the server-less architecture. In [23], the authors suggested the architectural system for the IoT based water meter. The Mediatek Server Sandbox was used as a cloud platform in the proposed framework for the cloud to interact with the water meter. The suggested framework used RESTful web services to communicate with the water meter and the IoT cloud and had the potential to analyze data at lower costs.

IV. SYSTEM DESIGN

In this paper, the proposed system aims to design an IoT-based smart water meter to monitor water consumption, taking into account the energy consumption of IoT sensor nodes. Fig. 1 shows the general structure of the proposed system.

The proposed system is designed by integrating a smart meter and Arduino Uno into the ESP8266 Wi-Fi module for various scenarios. The water flow sensor YF201B is used to measure water consumption. The key idea is that when water flows through the sensor, the magnetic rotor will rotate, and the rotation rate of the rotor will vary with the flow rate. The sensed data will be sent to the IoT-Fusion center via ESP8266 Wi-Fi. In addition, an effective water meter data collection (EDCDWM) algorithm has been applied to reduce the amount of data transmission. This process can reduce the energy consumption of IoT nodes. This is because the battery life of an IoT node is affected by the number of transmitted data packets. The EDCDWM algorithm has been described in detail in the next section.

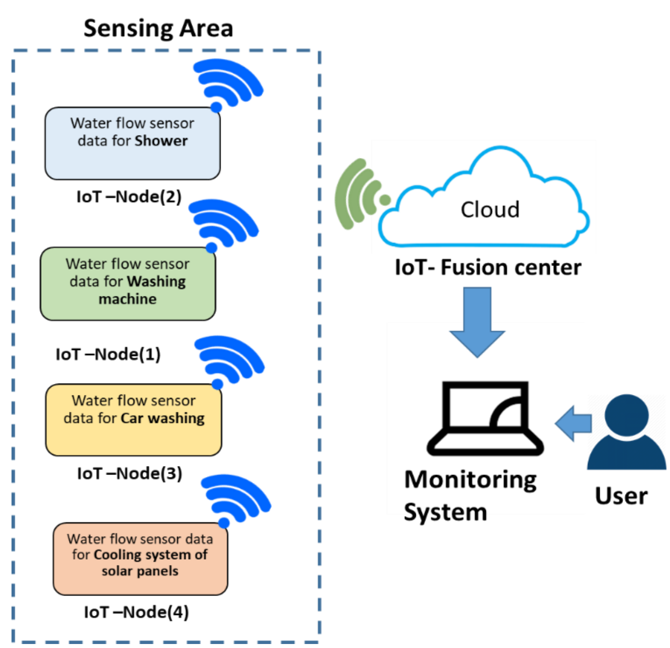

Fig. 1. System Structure.

V. EDCDWC Algorithm

In the section, we explained the proposed EDCDWC algorithm to reduce the number of transmissions. The proposed algorithm EDCDWC used in this study is described in the following pseudocode where it was deduced based on the EDCD algorithm [6]. It works based on the absolute change in the total quantity of water usage measured by the water flow sensor.

// ***SetupPhase //***

// Setup phase: In this phase, the IoT sensor board transmits one sample only.

Set $TM(t-1) \leftarrow 0$ *// previous TotalMilliLitre*
Call *Algorithm1- MWF*
$TM(t) \leftarrow MWF$
Send *TM(t) TO FC*
Set $TM(t-1) \leftarrow TM(t)$
END

Algorithm1: Measured Water flow (MWF)

Inputs: $T_p, T_c, WF, TM(t-1)$
Output: $TM(t)$ *// TotalMilliLitres in current time (t)*
Begin:
Set *CF = 6.8 // CF is sensor calibration factor*
Read *WF //water flow sensor value*
If *WF* == 1 *// water flow*
Set $T_D = T_c - T_p$ *// T_p is time of previous scan (ms), T_c is current time (ms)*
Calculate $FR = \left(\frac{1000}{P_c * T_D}\right) * CF$ *// FR is Flow Rate*
$FM = \left(\frac{FR}{60}\right) * 1000$ *// FM is flowMilliLitres*
Set $TM(t) = TM(t-1) + FM$
end if

// EDCDWM-AC Algorithm//

Inputs: $Thr, TM(t-1),\ TM(t)$
Output: *T // T=On/OFF transmite the data or not*
Begin:
Call *SetupPhase // call setup phase for one time only*
// Reduction phase//
Call *Algorithm1- MWF*
$TM(t) \leftarrow MWF$
Compute *Absolute change* ***(****$TM(t-1),\ TM(t)$* ***)***
$AC \leftarrow Abs(TM(t) - TM(t-1))$
$If\ AC > Thr\ Then$
Set $T \leftarrow 1$
Else:
Set $T \leftarrow 0$
End if
// The decision to Transmit data
If $T = 1$ **Then**
$Send\ \ TM(t)$ *// transmit (ON) and send data to FC*
Set $TM(t-1) \leftarrow TM(t)$
Else
// Transmit (Off) // No
End If
Wait // and Call *// Reduction phase//*
End Algorithm

// EDCDWM-RD Algorithm//

Inputs: $Thr, TM(t-1),\ TM(t)$
Output: *T // T=On/OFF transmite the data or not*
Begin:
Call *SetupPhase // call setup phase for one time only*
// Reduction phase//
Call *Algorithm1- MWF*
$TM(t) \leftarrow MWF$
Compute *Relative difference* ***(****$TM(t-1),\ TM(t)$* ***)***
$AC \leftarrow Abs(TM(t) - TM(t-1))$
$RF \leftarrow \frac{AC}{(\ TM(t)+TM(t-1))\times 0.5)}$
$If\ RF > Thr\ Then$
Set $T \leftarrow 1$
Else:
Set $T \leftarrow 0$
End if
// The decision to Transmit data
If $T = 1$ **Then**
$Send\ \ TM(t)$ *// transmit (ON) and send data to FC*
Set $TM(t-1) \leftarrow TM(t)$
Else
// Transmit (Off) // No
End If
Wait // and Call *// Reduction phase//*
End Algorithm

A. Validity and Reliability of the Sensed Data

In this study, a water flow sensor is connected to the pipe to measure the movement into the pipe, and the Hall effect of the water flow sensor converts the movement of water into pulses. If the valve of the pipeline is closed, the sensed output is zero (no pulse), but when the valve of the water is opened, the sensor converts the motion of the Hall effect into pulses and then converts it into a measured value. In addition, the calibration coefficient is used to represent the output of the Hall-effect flow sensor. As shown in Table II, this factor is adjusted for correct reading during the working period.

As the loop may not complete in exactly 1-second intervals, the number of milliseconds that have passed since the last execution is calculated to scale the output. The flow rate is also calculated based on the applied calibration factor, which scales the output of flow rate (FR) based on the number of pulses per second per unit of measure as shown in Eq. (1). In order to calculate the current flow of water, when the water stops flowing through the sensor, the time in this case will not increase. Accordingly, the current time of the water flow is equal to the time before the water flow stopped.

$$FR = \frac{(1000/CT - TP) \times CP)}{SCF} \quad (1)$$

TABLE II. Adjustment of Calibration Factor

Calibration factor	Actual value (ml)	Measured value (ml)
7.5	1500	1329
7.0	1500	1428
6.8	1500	1508
6.5	1500	1526
6.0	1500	1647
5.5	1500	1915

where, CT is the current time (ms), TP is the time of previous scan (ms), CP is the current pulse count and SCF is the sensor calibration factor.

Equation (2) is used to calculate how many milliliters have passed through the sensor each one second by dividing the flow rate (liters/minute) by 60, then multiplying by 1000. Thus, the final value of consumption can be obtained at any time. Equation (3) is used to calculate the total milliliters flowing through the sensor. Table III shows the initial values of the parameters of the water flow sensor.

$$FlowMilliLitres = \left(\frac{flowRate}{60}\right) \times 1000 \tag{2}$$

$$TotalMilliLitres = CurrentMillilitres + PreviousMilliLitres \tag{3}$$

TABLE III. PARAMETERS OF THE WATER FLOW SENSOR

Parameter	Initial value
Calibration factor	6.8
Byte pulse Count	0
Flow Rate	0.0
Flow Millilitres	0
Total Millilitres	0
old Time	0

B. Testing of Sensor

The sensor was tested by using a bottle of water with 1500ml capacity. Fig. 2 shows the testing process, where the bottle was filled four times. As shown in Fig. 2, the system consists of Arduino Uno, water flow sensor, a bottle of water, SD card memory, and a battery. These components have been connected to the system. During this process, the sensed values are 1511ml, 1491ml, 1500ml, and 1508ml, with an accuracy of up to 99% as shown in Table IV.

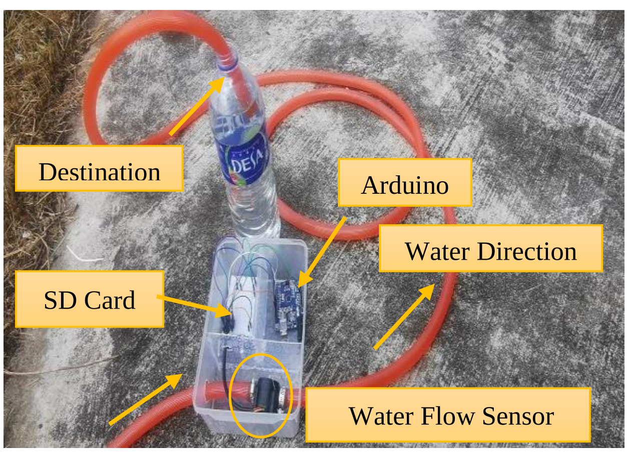

Fig. 2. Testing of Sensor.

TABLE IV. TESTING EXPERIMENTS

Experiment	Actual value (ml)	Measured value (ml)	Accuracy
E1	1500	1511	99%
E2	1500	1491	99%
E3	1500	1500	100%
E4	1500	1508	99%

C. Data Collection

To investigate the various approaches; absolute change, relative change and relative differences; the proposed algorithm was applied separately for the collected data from the washing machine, shower, car-washing, and cooling system scenarios as following:

- Scenario (1) - washing machine: The total number of transmissions is 2965. Fig. 3 shows the experiment of collecting data from the washing machine, while Fig. 4 presents the graph of collected data.
- Scenario (2) - shower: The total number of transmitted samples is 592. Fig. 5 shows the experiment of collecting data from the shower, while Fig. 6 presents the graph of collected data.

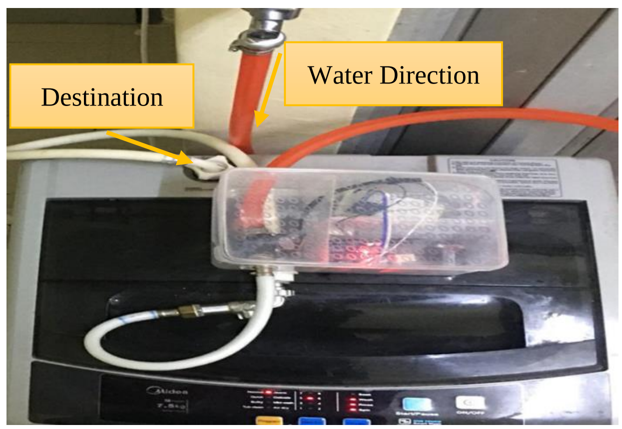

Fig. 3. Collection Data from Washing Machine.

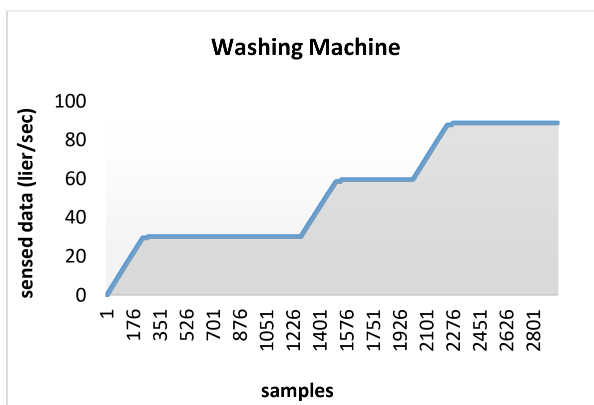

Fig. 4. Data of Washing Machine.

Fig. 5. Collection Data from Shower.

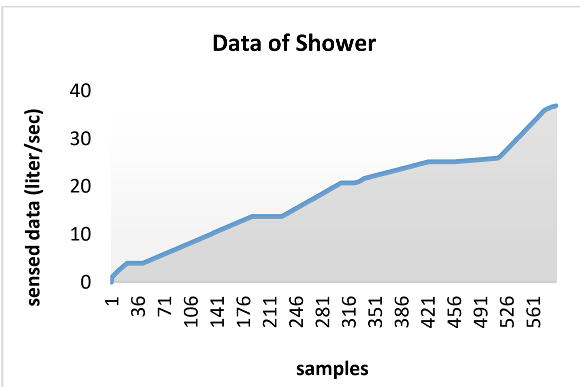

Fig. 6. Data of Shower.

- Scenario (3) - car washing-: The total number of transmitted samples is 1793. Fig. 7 shows the experiment of collecting data from car washing, while Fig. 8 presents the collected data.

Fig. 7. Collection Data from Car Washing.

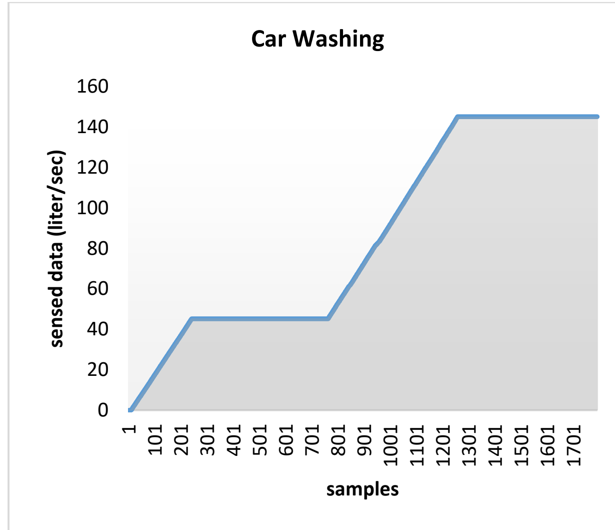

Fig. 8. Data of Car Washing.

- Scenario (4) - cooling system: The total number of transmitted samples is 14565. Fig. 9 shows the experiment of collecting data from the cooling system, while Fig. 10 presents the collected data.

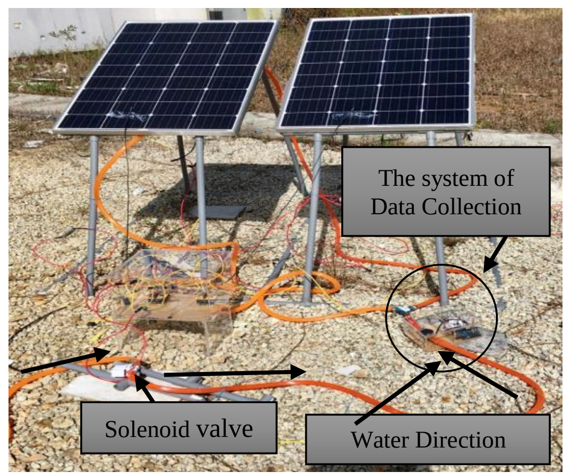

Fig. 9. Collection Data of Cooling System.

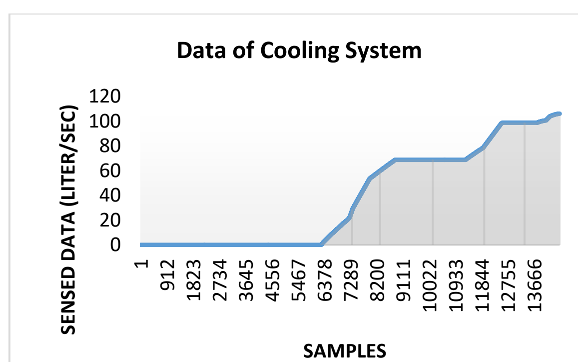

Fig. 10. Data of Cooling System.

D. Performance Evaluation of EDCDWM Algorithm

The EDCDWM algorithm with the applied threshold has been tested in various scenarios. In node (1), the data samples collected from the washing machine are 2965 samples. For the Node (2) and (3) (i.e. for shower and car washing scenarios, respectively): the data samples are 592 and 1793 samples, respectively. For the last node, i.e. Node (4), the data samples collected from the cooling system for solar panels are 14565 samples.

The algorithm was evaluated in terms of the number of transmitted data and energy consumption reduction during the transmission process. The experiment parameters are shown in Table V, where the applied threshold *Thr* is 0.03, and the cost of transmitting one byte is 59.2 µJ.

TABLE V. EXPERIMENT PARAMETERS

Parameter	Value
Thr	0.03
Algorithm	EDCDWM
Sensor	Water flow
Cost of transmitting one byte	59.2µJ
Size of one sample	4 bytes
Cost of transmitting one bit	59.2/8 µJ

Fig. 11 shows the comparison between three ways to send data from water flow sensors to the cloud, direct transmission and transmission by EDCDWM-AS and EDCDWM-RD algorithms. As it noticed that the transmitted processes were from four nodes for different scenarios. Fig. 10 shows the amount of data transmitted by different nodes/scenarios. The graph shows that the number of transmitted data directly was 2965 samples for node (1). In comparison, it was about 717 samples by using EDCDWM-AS algorithm, while the number of packet transmission was decreased sharply to reach 122 samples by applied EDCDWM-RD algorithm. For node (2), the number of transmitted samples reduced by applying the EDCGWM-AS algorithm is 150 samples. The number of transmissions has changed from 592 samples directly sent to 442 samples, and the transmitted data is reduced to 88 samples transmitted through the EDCWDWM-RD algorithm. For node (3), it is clear that the number of packets transmitted decreases by the applied EDCDWM-RD algorithm compared with the EDCDWM-AS and direct-transmission. The number of packets transmitted is 126, 732 and 1793 samples for EDCDWM-RD, EDCDWM-RD and direct-transmission. Respectively. Finally, for node (4), the number of packets transmitted is 177, 11813 and 14565 samples for EDCDWM-RD, EDCDWM-RD and direct-transmission, respectively.

Fig. 12 represents the energy consumption for the tested scenarios with the three transmission algorithms. From the figure, it is clear that EDCDWM-AS and EDCDWM-RD transmission schemes were able to reduce the energy consumption significantly compared with the direct transmission scheme. For example, EDCDWM-AS was able to reduce the energy consumption for node (1) by around 76%. In contrast, EDCDWM-RD was able to save energy by 96%. For the node (2) the consumption of energy is less than other nodes, and about 25% saving in energy was achieved by EDCDWM-AS, and 85% achieved by EDCDWM-RD. In node (3), the percentage of energy consumption was about 59% for EDCDWM-AS, and around 93% for EDCDWM-RD. The consumption of energy was decreased sharply in node (4), where about 81% reduction is obtained by EDCDWM-AS, and around 99% by EDCDWM-RD. Overall, from these shown experimental results, it is very clear that decreasing the amount of packet transmission results in a reduction in energy consumption as well as extending the meter battery life. Although EDCDWM-based schemes reduced data transmission, it did not affect the calculation of the actual water consumption value.

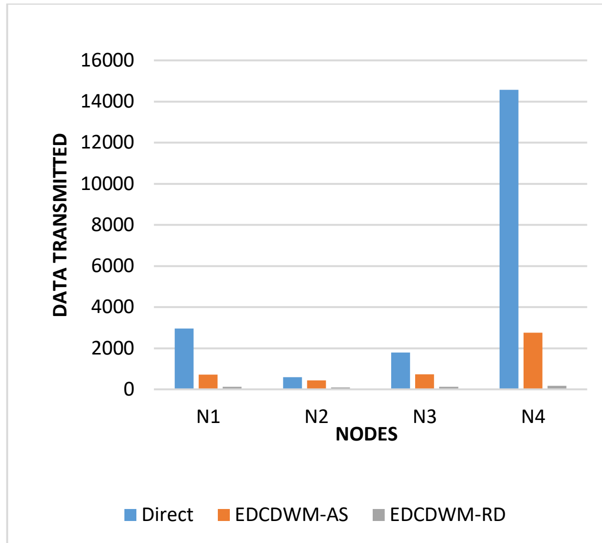

Fig. 11. Transmitted Data.

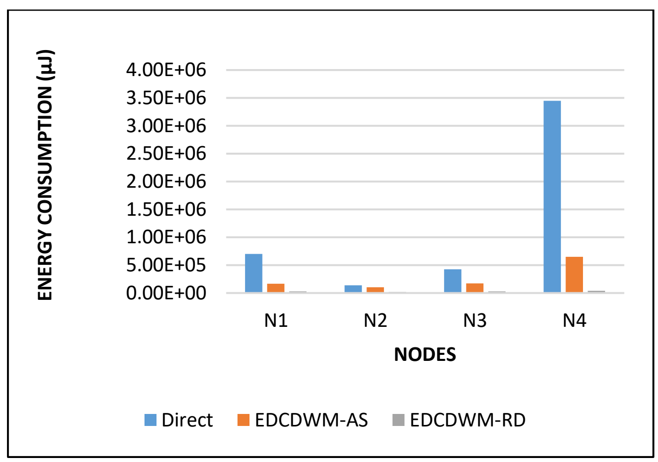

Fig. 12. Energy Consumption.

Fig. 13 provides the percentage of data transmitted for various sensor nodes to the cloud using EDCDWM-AS and EDCDWM-RD algorithms. The data reduction rates achieved by applying EDCDWM-RD to N1, N2, N3, and N4 are 96%, 85%, 93%, and 99%, respectively. In contrast, applying EDCDWM-AS to N1, N2, N3, and N4 achieved data reduction rates of 76%, 25%, 59%, and 81%, respectively. It can be seen from the results that EDCDWM-RD has better performance than EDCDWM-AS in terms of the data reduction rate of all nodes.

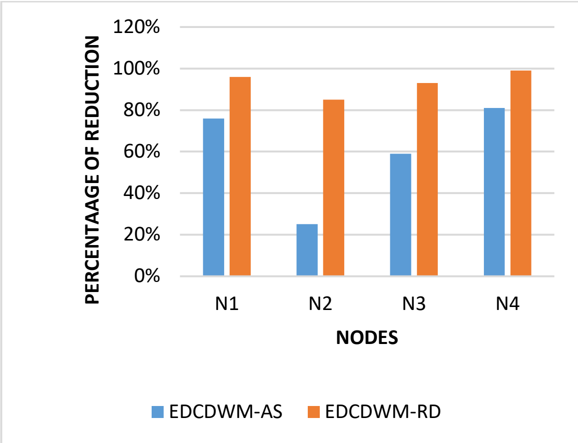

Fig. 13. The Percentage of Data Reduction.

E. System Implementation

The smart water meter is designed using NodeMCU with a Wi-Fi module and a water flow sensor as shown in Fig. 14. When the water passes through the sensor, the Wi-Fi is sending the value of flow rate and the total quantity of water to the Cloud platform, which is in this research Thinger.IO platform. Besides, two Wi-Fi modules have been used. The first one is used to send the measured values directly while the other one sends the measured values based on the EDCDWM schemes.

Fig. 15 shows the transmitted data to the cloud platform directly as one packet per second. In contrast, Fig. 16 shows the transmitted data using EDCDWM. In summary, it is clear that the applied algorithm is able to reduce the number of transmissions without any effect on the total quantity of the water usage.

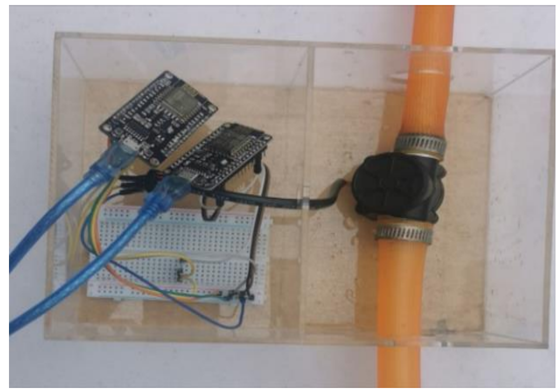

Fig. 14. Smart Water Meter based IoT.

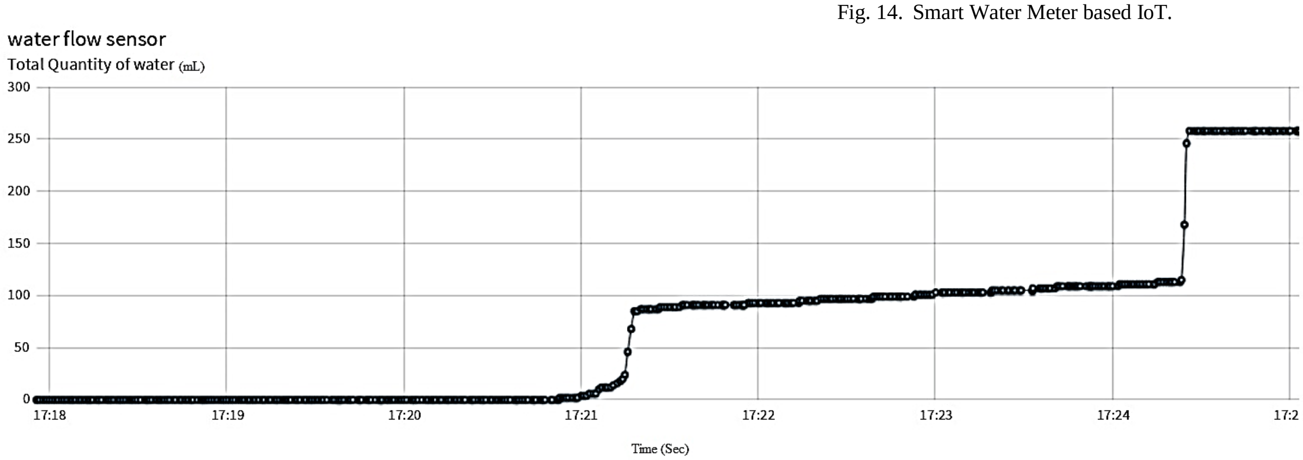

Fig. 15. Transmitted Data Directly.

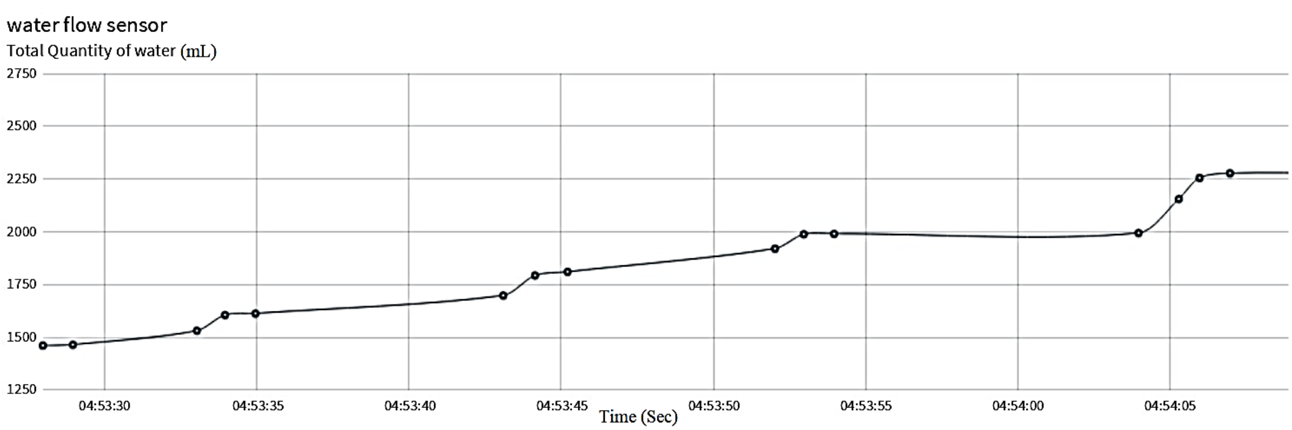

Fig. 16. Transmitted Data via EDCDWM.

VI. Conclusion

In this paper, an energy-efficient IoT-based smart water meter has been developed and tested with different scenarios. Energy saving was achieved through reducing the amount of data collection and transmission using the EDCDWM scheme. The performance of this applied data-collection scheme has been measured. From the experimental results, it is clear that the applied data-collection scheme is effective in reducing energy consumption by reducing the number of transmissions. The percentage of energy saved by using the EDCDWM-AS scheme in the nodes (1), (2), (3), and (4) are 76%, 25%, 59%, and 81%, respectively, with an average of 60% energy saving. The EDCDWM-RD scheme shows better results for the same nodes, where the percentages of energy saved for the nodes (1) - (4) are 96%, 85%, 93%, and 99%, respectively with an average of 93%.

As a future work, we will connect the smart meter with a valve to control the water flow when there is a leak. Furthermore, the system software will be improved to add more features, such as giving the users the ability to reset their recorded usages of the water in the cloud and paying their bills automatically.

Acknowledgment

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White-Grey-Black Hat Hackers Role in World and Russian Domestic and Foreign Cyber Strategies

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***Abstract*—The article aims at establishing the role of three different types of hackers in the domestic cyber space, policy and welfare, international relations and warfare of the Russian Federation compared to the situation in the world as for the beginning of 2020 year. The character and structure of hackers' participation in the information policy and cybersecurity are characterized in connection with the intensity and duration of their intervention, national interests, technical and political outcomes. The new role of cyberwarfare as the fifth sphere of military activity is highlighted and proved. Positive and negative influence of hackers' activities, methods of their detection and control on the level of an individual Internet user, company, government and international organization are differentiated. Examples of certain criminal groups of hackers' activities are given. Main organizational measures, tools and cryptography techniques for the protection against hackers' invasion are proposed. The article reveals and analyzes the specifics of various hacker attacks: white, gray and black. The article emphasizes that cybersecurity in the world is now the object of hacker attacks, which can affect the functioning of not only national or private corporations: but also, the work of government agencies.**

***Keywords*—Cyber wars; cybercriminals; disinformation; espionage; hackers; information security; military technology**

I. Introduction

Peace and the war states in the modern era are separated by the thin line. There is no longer need to declare a certain and to follow a certain template. For organization of the anti-government protests, misguideness of adversaries, disorganization of the governance, public opinion influence, and reducing an opponent's resistment the disinformation is used; intelligence, military, and agencies of law enforcement prioritizing IT security for investing and recruiting [1].

At NATO Summits in Bucharest (2008) and Lisbon (2010), cybersecurity was first included in the strategic concept of position on cyberspace as new fifth sphere of military activity alliance. This direction was dynamically developed at the NATO summit in Wales (2014) and has become one of the keys on subsequent, including parliamentary, assembly organizations [2].

In the modern war it is impossible to achieve the set goals without constant implementation of information fighting measures. In peacetime, information warfare becomes an important component of the deterrent potential of the enemy. The strategies and motivations of those involved in cyberwarfare are often hidden by its technical nature, rapid evolution, and covert methods of use. Russia also succeeded in integrating cyber warfare into the state strategy for political domination [3].

In US cyber strategy, Russia, China, Iran and North Korea are treated as opponents using cyberspace to challenge the United States, its allies and partners. Donald Trump repealed the rules on the implementation of cyber-attacks, approved by the directive of B. Obama, wherein the United States prioritizes strengthening information component of the potential of hybrid warfare, the creation of a global electronic surveillance system and robotic on social networks, aimed at inspiring "cyber rebellion" in Russia [3]. Cyberwarfare no longer concerns only computer ports and protocols. Professional trolls are able to create misleading content and share it worldwide. Kevin Mitnick, famous hacker, stated: "it's easier to manipulate people rather than technology." Military operations now are usually preceded by information operations for the potential battle space preparing [1].

Hacker attacks are usually technical in nature (for example, malicious ads that inject dangerous objects onto a computer in the shadow mode and do not require user participation). However, hackers can also use psychological methods to trick users into opening malicious attachments or providing sensitive data.

At the end of 2020, Sunburst launched a stunning hacking attack on US and global targets, including SolarWinds, a leading US network management company, launching a monitoring platform that provides IT support staff with access to devices on which it is installed) allowed to break the function of updating its program. According to representatives of the cybersecurity company FireEye, which helped expose the hacker attack, said that many organizations around the world could be at risk, although the main target of this attack, apparently, were US authorities.

At the same time, it should be noted that throughout 2020, cybersecurity experts around the world have seen a surge in hacker attacks on critical infrastructure, including organizations involved in the fight against the COVID-19 pandemic.

II. Literature Review

With the development of Internet technologies, the development of artificial intelligence - hacker attacks, hacking as a phenomenon and cybersecurity are becoming the object of scientific research.

In particular, it is worth starting a review of scientific accentson different types of hat hacker. According, Banda, Phiri, Nyirenda, Kabemba, computer crimes have been in existence for a long time now and hacking is just another way or tool that hackers are now using to perpetrate crime in different form. In their opinion, the following are some of the consequences of network attacks: 1) Intermittent Business: Even small cyber-attacks can disrupt business. This may result in financial information and interrupted inventory to a complete digital shutdown. This may result in the denial of service (DOS); 2) Data Loss: Data lose may result in compromised consumer privacy and agency. Fines and Legal Consequences: Apart from properly reporting the depth and breadth of a cyber-attack, your business could face specific government-mandated “mishandling” fines, plus lose compliance or standard certifications; 3) Overall Loss of Business: Technology consumers will least trust a company whose resume is tarnished with digital maladministration. This directly affects the company’s ability to stay open [4].

If we are talking about the study of white hat hackers, it is worth mentioning the study Goel, Gupta, Garg. In their opinion, white hat hackers these are ethical hackers. They try to find out weaknesses of the computer system or the network with the help of penetration testing and vulnerability assessments. Their main intention of doing so is not to harm the system but to help. A white hat hacker breaks security for non-malicious reasons, perhaps to test their own security system or while working for a security company which makes security software. White hat hacker’s job is one of the demanding jobs available in IT industry and its ethical hacking. White hat hackers these are Ethical Hackers. They try to find out weaknesses of the computer system or the network with the help of penetration testing and vulnerability assessments. Their main intention of doing so is not to harm the system but to help. A white hat hacker breaks security for non-malicious reasons, perhaps to test their own security system or while working for a security company which makes security software [**5**]. White hat hacker’s job is one of the demanding jobs available in IT industry and its ethical hacking.

Nanda think, that the white hat hacking plays a significant role in securing the information systems that is crucial in our computer driven world. That is not to say that it does not present some ethical problems in itself but if it is used correctly, it has tremendous potential in helping to secure information. Much of its success will come down to the morals and ethics that are at the core of the individual hacker. The more ethical-minded the individual, the more trust-worthy and beneficial that individual white hat hacker will prove to be [6].

The study Goel, Gupta, Garg "Ethical Hacking and Its Countermeasures," described above also the phenomena of black and gray hat hackers. Grey hat hackers, in their opinion, are a combination or blend of both black hat and white hat hackers. They act without malicious intent but for their fun, they exploit a security weakness in a computer system or network without the owner’s permission or knowledge. The intention behind their work is to bring the weakness to the attention of the owners and getting appreciation or a little bounty from the owners. A grey hat hacker is a combination of a black hat and a white hat hacker. A grey hat hacker may surf the internet and hack into a computer system for the sole purpose of notifying the administrator that their system has a security defect, for example [5].

If we talk about black and gray hat hackers, mentioned above Goel, Gupta, Gar, that they are people who hack the system illegally. When they gain unauthorized access to a system their intentions are to harm its operations or steal sensitive corporate data or secret information. They can also violate privacy block the system network communication, overload the system so that it becomes too slow, etc. A black hat hacker is a hacker who "violates computer security for little reason beyond maliciousness or for personal gain" [5].

Pelton, Indu B. Singh believe that the problem of cyber-attacks, invasion of privacy, stolen data, and identity theft will become ever more difficult to block, because the torrent of information exchange will only become larger and faster and more internationally diverse. The new cyber world that unfolds ever more rapidly each day will bring new opportunity for education, training, business, global economic exchange plus gaming and amusement, but it would be misleading to suggest that there is likely to be a silver bullet to stop cyber-crime and cyberterrorism. If you operate a business, it would be very prudent to follow the five-step program in the new U. S. cybersecurity framework. This means taking action to: “Identify, Protect, Detect, Respond and Recover.” [7].

Black-hat hackers in darknet are often on the borderline between cyber-libertarians and outlaws. Regardless of different views on their rightfulness, there is a consensus about the importance of understanding organizational workings in their communities [8].

Considering the current research on hockey attacks, it is worth making a number of emphases on scientific developments in the context of cybersecurity. Cybersecurity has emerged as a global challenge and is becoming a tier one security threat for nation states. Cyber incursions are complex and difficult to detect. They are extremely subversive. These challenges are even enhanced by developing AI, which bring new tasks for cyber security specialists. It is the cyber attacks that pose the biggest challenge to states and personal data [9].

According to Sharma, artificial Intelligence (AI) is a popular expression in the digital world. It is as yet an emerging science in various features as indicated by the difficulties experienced in the 21st century. Nowadays one can't imagine a world without AI as it has had a gigantic impact on human life. Computer-based intelligence is in almost every sphere of human life, including gaming, language preparation, discourse acknowledgment, insight robots, money-related exchanges, and so forth; every movement of human life has become a subset of AI. Security issues have become a significant threat for governments, banks, and associations due to online ambushes by software engineers. AI and cyber security have expanded and become more essential in the progressing events but AI is suffering also as it is a dynamic and fragile issue associated with human life [10].

Information security becomes a cornerstone of creation of communication networks of future generations and how data and communication networks will be protected safety of Society and State will depend. If today objects, potentially vulnerable from the Internet, are computers and the maximum harm which hacker attack can cause is a temporary suspension of work of automated control systems and access to information, any element of Digital economy can become object of attack in networks of the Industrial Internet of things. [11].

III. Methodology

Statistical reports and recent time historical backgrounds are implemented into each part of the article, discussed and compared for identifying the conceptually important patterns and responses. The character and structure of hackers' participation in the information policy and cybersecurity are characterized in connection with the intensity and duration of their intervention, national interests, technical and political outcomes.

In this article, the main scientific methods used are search, comparative, analytical methods. From the point of view of the specifics of the article - cybersecurity and hacker attacks, as well as its nature - the review article took into account and analyzed the materials of specialists in cybersecurity, countering hacker attacks and hacking in general as a phenomenon in cyberspace, which certainly affects government data protection policies.

IV. Result and Discussion

A. Hackers Activities for Peaceful Purposes

The attitude in the software industry for the term “hacker” has shifted from a positive “smart programmer” to a negative meaning “a person who uses computers to gain unauthorized access to data.” (Fig. 1).

Nevil Maskelyne in 1903 managed to perform one of the earliest examples of hacking. It was the disruption of wireless telegraphy technology (invented by Guglielmo Marcony) by John Ambrose Fleming during its public demonstration. Maskelyne used auditorium's projector to send insult Morse code messages. Maskelyne drew attention to the technology's flaws and showed that interference is possible. He organized his Royal Institution hack with the use of a simple transmitter and Morse key at the West End music hall owned by his father [36].

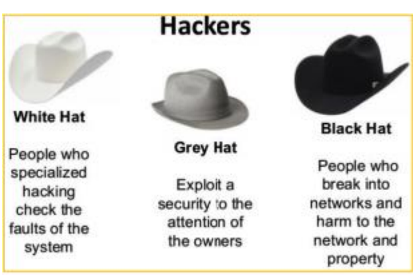

Fig. 1. Three main Types of Hackers.

1) White hat hackers or cybersecurity experts: In a professional environment there are "white" (or ethical, or white hat) hackers. Thanks to them a chance to gain access to customer data is reduced significantly. Some of hackers earn considerable sums of money from "bug bounties" from giant software corporations. For example:

- U.S. Army, Google, Microsoft, Pentagon pay them for breaching their security and exposing vulnerabilities. To identify vulnerabilities in their products Apple and Microsoft (e.g., Pwn2Own) encourage and sponsor hacking competitions. Vulnerability Rewards programs (VRP) from PayPal, Firefox, Google and others encourage hackers to disclosing and testing vulnerabilities [12].
- Most developers of information security systems of Rostelecom are white hat hackers. They are not inferior to grey and black hat hackers in either knowledge, experience, or ingenuity. They apply their talent in the legal field, in the interests of the law and the protection of information [13].
- For the first time, some companies (Zerodium and others) used an advertisement for the purchase of security vulnerabilities in order to transfer them to government clients for use in espionage. Zerodium payed $2million to white hackers in January 2019.
- Apple offered ethical hackers more than $1m for iOS kernel weakness discovering. And if the bug is found in pre-release software, company pays for a single bug 50% more [14].

2) Grey hat hackers: This type of hacking is illegal in most instances, though not inherently malicious. They expose vulnerabilities in systems without any permission given from the owners. Fee is requested by a gray hat for not disclosing it. And, if the organization doesn't fix the problem quickly enough, they will publicly disclose the vulnerabilities. In recent years, these hackers put much attention to the Internet of Things security issues due to such devices' growing ability to affect people's everyday life on macro and micro level and, therefore, the catastrophic repercussions of the IoT system violation [15]. For example:

- Thousands of Asus routers' users were left text warnings reminding to make patches when they were hacked by grey hats in 2014.
- A malware to close security vulnerabilities in several Linux routers were released by a group of grey hackers self-proclaimed as “White team” in 2015.
- A malware program able to delete firmware or brick the unpatched IOT gadgets was released by a grey hat in 2017. Later this year, more than 100,000 printers printed warnings about the leaving the devices exposed online being dangerous.

- In 2018 Catalin Cimpanu by ZDNet reported: grey-hat hacker Alexey had broken into and patched over 100,000 MikroTik (Latvian-based company dealing with routers and wireless ISP systems) routers to close the exploit that could be used by crypto-miners. Most hacked devices' owners were angry at invasion. Only near 50 people have contacted him to thank. Later this year, to make thousands of owners update their MikroTik and Ubiquiti routers another grey hat renamed them "HACKED" [16].

Grey hackers make the software market more competitive. Since grey hackers are working with largely used platforms, all users will benefit from their actions. Moreover, such activity can help the population of developing countries where governments often implement electronic documentation systems with little to no regard to their security [17] by increasing public awareness of such situation's potential risks and dangers.

However, grey hackers' actions are debated regarding their outcomes:

- Andrew Aurnheimer' charge of disclosing (exploiting website vulnerability) 114 thousand emails of iPad owners to AT&T;
- Downloading articles without subscription containing JSTOR research leaded to the prosecution of Aaron Swartz.
- Mathew Keys was charged for providing a website account's password of Los Angeles Times [18].

An act of discovering a vulnerability in a software could be acknowledged as criminal activity according to CFFA law.

B. Hackers Activities for The Criminal, Political and War Purposes

1) Black hat hackers or cybercriminals: Black hackers are ranged from amateurs to experienced criminals. Sometimes they are supported by goverment or terrorists or the employees or former employee of the attacked organization. They exploit information or sell it on the black-market to gain money. Such group like Fancy Bear, for example, is government employed and a group like Magecart acts independently. Among organized worldwide known groups such as "Swagg Security", "LulzRaft", "the Hacker Encrypters", "Team Appunity", "Lulz security", etc can be distinguished.

Due to the fact of having a developing economy, great wealth in Russia and countries of East Europe is monopolized. Also, the heritage of Soviet Union, made people used to free of charge products. A great gap between the quantity of educated in math, science and computers people and work opportunities pushes them towards illegal activities. Hackers originated from Russia and East Europe is known among the best in the world, so other states hire them for cyberattacks.

2) Features of russian hackers: Hacktivists from Russia and cyber-criminal syndicates became famous worldwide due to such features as:

- anonymity;
- easy to hire;
- crowdsourcing utilized by hackers and criminal networks;
- support by government agencies [1].

3) Interference into the election process in the own country: For such purpose hackers use different methods to disrupt voting trough Internet:

- Spoofing attack method. It is a legitimate message or resource imitation that is offered to voters. The fake voting website and the official website are visually functioning and look similarly. The attacker receives voter's identification data and can use it on the real voting website.
- Pharming attack method. It is a traffic redirection from one website to another. One way is to change voter's computer settings; another way is to exploit DNS (domain name server). Another name of attack of this type is DNS poisoning, falsifying DNS records so that a voter is directed to a fake voting website.
- Attacking against the website. It is a type of a hybrid attack achieved by inserting website-dependent malicious code that leads to lose of the voting possibility [19].

4) Examples of hackers activities for the war and foreign policy purposes

- In Europe. DDoS (Distributed denial of service) attacks like one that happened in Estonia against NATO-related cyber security center website [1]. Near 2,5 thousand confirmed attacks and 147 million "suspicious events" happened every day on computers at Mons (Belgium) cyber defence centre of NATO in 2013 [20]. TV5 Monde French television network and German Parliament were also subject to hacking attacks.

World disinformation: Since 2013 in St. Petersburg IRA (Internet Research Agency) was developed, also known as a 'troll factory'. Propaganda for both domestic and international social media such as Facebook, Instagram, Twitter and YouTube are created there. IRA's ad volume on Facebook peaked in April 2017, the same month as the introducing of tax reform plan and when ISIS tunnels in eastern Afghanistan were striked by Syrian missile [21].

World espionage: During the MH17 Belgian, Malaysian, Dutch, Australian, and Ukrainian authorities' investigation Russian cyber espionage campaign derailed.

In Georgia: The first known wide-scale offensive cyber operations in conjunction with conventional military operations were conducted by Russian hacktivists websites, such as stopgeorgia.ru on the first day of war in Georgia. Lists of Georgian sites to attack and downloadable malware, instructions and after-action assessments were made public. Most perpetrators traced to Russian and Turkish servers. Right before air attacks on the city of Gori their news websites and government websites were affected. Georgian government had to reroute most traffic through servers of other countries, such as Estonia, Poland and the United States due to IT infrastructure limitations in 2008 [1].

In Ukraine: During the Russian-Ukrainian conflict Russian hackers conducted malware attacks, spear phishing (sensitive information stealing), DDoS attacks, along with the actions of Russian military forces: TDoS (telephone denial of service) attacks, seizing an IXP (Internet Exchange Point), Internet cables' damaging, getting access to public CCTV cameras in the East of Ukraine, etc. Ukraine's military, government, private-sector, information technology infrastructure and telecommunications were targeted [22]. For example, CyberBerkut hacktivist group made public stolen, sensitive information against Ukrainian independency and proclaim themselves as defenders of Ukrainian national interests against aggression of West. On the eve of President of Ukraine elections in 2014, the group CyberBerkut damaged the IFES system of the Central Election Commission of Ukraine [19].

In USA: As US researchers state, the Main Directorate of the General Staff of the Armed Forces of the Russian Federation, abbreviated G.U. applied coordinated hacking to attack over 5 hundred institutions and people in US by exposing hidden information via WikiLeaks and other aliases such as "DCLeaks", "Guccifer 2.0." In March 2016, G.U. sent deceiving emails to more than 3 hundred people related with the Democratic Congressional Campaign Committee, Democratic National Committee, and Hillary Clinton's presidential campaign. Campaign chairman John Podesta was affected, as a result, more than 50 thousand secret messages were unwittingly handed over to the Russians [23]. North Korea's hack of Sony Pictures was also suspected of being conducted by Russian hackers.

Cyber-attacks against RF: The country ranked second in number of cyberattacks — 10% of all world cyberattacks accounted for Russia. According to international cyber experts, Russia suffered as a result of WannaCry cyber-attack in May 2017: most damage have been brought to the work of computer systems of the Ministry of Internal Affairs, Ministry of Emergencies, Russian Railways, Sberbank and "Megafon". Another massive virus attack was in June 2017: ransomware virus Petya blocked access to data, demanding for the unlock US$300 in Bitcoins. Individual versions of Petya disguised as a resume. Though the Petya virus is powerless without gaining administrator rights, its improved version — the Misha virus — is vested with administrator rights in advance [24].

C. Current State of Cybersecurity

1) Number of breaches by years

- In 2013, there were near 4 million records stolen from breaches every day; near 160 thousand per hour; about 3 thousand per minute or 44 every second. It takes about 6 months to detect data breach for most companies [25].
- In 2016, retail, government and technology are targeted in 95% of breached records. It is a 126% more than in 2017. In January 2016 it estimated 500 million Yahoo users accounts targeted.
- In May 2017, according to Equifax, data on 143 million Americans was exposed [18].
- In 2018, half a billion of personal records were considered stolen.
- 2019 year was proclaimed the year of data breach. Breaches used for exposing the records have risen by 54% (to near 4 billion) as for the second quarter of the year. 71% breaches were made for money gain and 25% – for espionage. 28% applied malware and 32–33% with phishing or social engineering, and 52% of hacking-related breaches.
- By 2021, according to Cybersecurity Ventures, the cybercrime damage can reach up to $6 trillion [26].

2) New vulnerabilities and possibilities: New vulnerabilities appeared at the beginning of 2020 year in world social network. Twitter has revealed details of cyberattacks, during which third parties used the company's official API to map phone numbers to social network user names. Security researcher Gal Weizman from PerimeterX has revealed a potentially dangerous Open Redirect vulnerability that allowed an XSS attack to be sent by sending a specially crafted message. If the victim views a malicious message, the attacker will be able to execute arbitrary code in the context of WhatsApp domain [27].

The weakest link in the security chain is considered the human factor. It results in 95% of cybersecurity breaches. Transferring personal data during an incoming call from an unknown number, a PIN code stored with a bank card, a password from an account on the work network glued to the monitor screen, clicking on random links from an office computer — all this creates ideal conditions for cybercrime.

As possibility to track and visualise global hacking real-time malicious activities the Kaspersky Cyberthreat is used [18].

D. Methods of Increasing Cybersecurity

1) Cryptography techniques: Digital image security has now attracted extra attentiveness. Cryptography and steganography techniques (permutation of pixel position, pixels value conversion etc.) were proposed to overcome the problem of information protection [28]:

- scan patterns,
- quantum chaotic maps,
- linear hyperbolic chaotic systems,
- quantitative cryptanalysis,
- chaotic nonlinear adaptive filtered,
- a linear quad tree compression etc.

Also, there are various math methods used:

- Lagrange interpolation to guess the value of the unknown values, use of nonlinear distortion cancellation for nonlinear compensator synthesis;
- Quadratic number spirals used in key image to create other types of spirals [29].

E. Main Organizational Measures, Tools and Software for Cybersecurity

1) Detecting unrecognized individuals and not letting people without appropriate accreditation into secure areas.

2) Restrict not required use and access of applications to the Internet.

3) Using Userfocus tool for mapping of attacker's procedures, monitoring attack methods for understanding the offenders' actions and for their prevention by individual techniques and tools [30].

4) Antivirus software use with updated signature databases and licensed, updated operating system and software.

5) Use of differential privacy when analyzing data to minimize the risk of users' sensitive information disclosure [31].

6) Clear explanation of every change taking important role for big corporations. For example, dual-factor authentication [32].

7) Hosting regular education sessions, but avoiding information overload which can be dangerous. It's better to use humor, repetition, short films, quizzes or collaborative workshops for better perception of complex material.

8) Due to the modern situation when people of different age groups work together under the same roof, company managements should use for training purposes the channels appropriate for every type of learner: audio, visual materials or practical activity.

9) Use of new tools for fake sources detection. For example, Alphabet-owned Jigsaw has released a free tool that allows journalists to detect fake photos, including those created using artificial intelligence [33].

10) Provide companies with the ability to retrieve and analyze information about their databases without profile tracking or invasive identity. These measures can also help to mitigate data breaches since sensitive data contained with other noise. In September 2019, Google announced set of libraries (open source) that offer the equations and models to set boundaries and limits on data identification and interface for developers to implement security [34].

11) The iOS platform is slightly less vulnerable to hacks compared to the Android platform [18].

12) Financing of cyber security sector and providing it with more responsibility. For example, in Canada two organizations are responsible for cyber security: PSC (Public Safety Canada) oversees the CSE (Communications Security Establishment) and the new CCCS (Canadian Centre for Cyber Security). The RCMP (Royal Canadian Mounted Police) is in the process of creating a National Cybercrime Coordination Unit. The Canadian government have decided to spend more than $500 million in five years beginning from 2018-2019 for realizing the National Cyber Security Strategy (28). It is better to invest in marketing campaigns to encourage competing software users to switch, than invest in developing more secure software, according to Sen, Verma and Heim (2020) investigation.

13) Provision of e-voting security procedures. For example: ensuring that voters receive an authentic electronic ballot and voter's information is destroyed immediately after receiving valid voting results; restricting connection to the e-voting system after the end of elections and integrity of the received data checked [35].

14) Special network access controlling systems use: 802.1x standart (checks profiles on the server and grants them access rights), Demilitarized zone tool (DMZ) (ensures public servers' security, establish two-step), Public Key Infrastructure, Intrusion Detection System, Web Application Firewall, TLS 1.2 (secure protocol latest version with symmetric and asymmetric encryption methods) along with well-developed PKI [19].

V. Conclusion

The year 2020 showed unpreceded number of data breaches and new vulnerabilities appeared at the beginning of 2021. The expenses on cybersecurity are growing. The cybersecurity process itself is based on a risk-oriented approach that identifies cyberspace assets and stakeholders, threats, recommendations and risk management measures, moreover, coordination guidelines are used as a specific measure actions and information sharing.

Human factor is considered to be the main problem for e-security. Supply of essential services can be affected by Cyber security incidents (providing healthcare, mobile network, electricity, water) and the critical infrastructure can be damaged.

The use of new tools for fake sources detection, special network access controlling systems, provision of e-voting security procedures, financing of cyber security sector and providing it with more responsibility, using appropriate channels to educate every learner, new steganography and cryptography techniques, mapping of attacker's procedures, constant implementation of information fighting measures, using the white hat expertise via bug bounty programs and responsible disclosure policies are the main sources to survive in a cyber war that continues to expand worldwide.

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Mobile Computational Vision System in the Identification of White Quinoa Quality

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***Abstract*—Quinoa is currently in high commercial demand due to its large benefits and vitamin components. The process of selecting this grain is mostly done manually, being prone to errors, because many times this work is subject to fatigue and to subjective criteria of those in charge, causing the quality to decrease due to not making an adequate selection subject to standards. For this reason, a study focused on determining the influence of the computer vision system for the identification of the quality of white quinoa, based on the standards and techniques for the development of a computer vision system through the phases of PDI. Managing to determine the influence of this, concluding that it is possible to ensure the implementation of robust systems to solve problems by applying computer vision thanks to technological advances for mobile devices.**

Keywords*—Computer vision system; quinoa quality; digital image processing

I. Introduction

La Quinoa is an Andean grain with great biological diversity. It is a product with a high content of macronutrients, amino acids and minerals, and is the basis of the diet of the inhabitants of the Andean areas [1]. According to WHO and FAO [1][2], quinoa is the ideal food for humans, because its protein contains the best balance of amino acids, including the eight essential amino acids, which cannot be produced by the human body. It is an easily digestible food, recommended for coeliacs, diabetics and those with lactose intolerance; due to its nutritional characteristics it is a substitute for meat or milk.

According to data provided by FAO [2], the main producing countries are Peru and Bolivia. Our country is the first producer of quinoa followed by Bolivia, leading the world production of quinoa with approximately 52% of world production and Bolivia with 45% [3].

Peru has become one of the largest exporters around the world. The global showcase of quinoa and the high pressure of its demand allowed the improvement of its prices and the incentive to plant larger areas of quinoa, especially in certain regions of the coast where it had not been produced before, such as Arequipa (coastal part), Lambayeque, La Libertad, Tacna, Lima and Ica. Production was also expanded and consolidated in highland regions such as Ayacucho, Junín and Huánuco. [1].

Quinoa for its commercialization and export [3] has to go through different post-harvest processes, the last one being the classification and selection stage, in some places this process has ceased to be manual, giving way to technification, where the grains are passed through a sorting machine with different mesh sizes, thanks to these processes, the product acquires a quality to be sold in markets or supermarkets. This method has very high costs due to the machinery used.

The selection process consists of classifying the grain according to size, weight and color through a manual or mechanized method; the first is appropriate for small quantities and the second for large volumes, in this process air and sieve machines, densimetric or predator table and the optical selector can be used [4][5].

One of the factors that can affect the final quality of the grain is the presence of a certain number of defects that are called "percentage values of its characteristics" such as: broken grains, immature grains, contrast and impurities, as well as the average diameter of the grains. [6]. The identification of quinoa grain quality is one of the most important criteria for commercialization, since the costs of national and international markets vary according to the quality level of the product. For this reason, a mobile computational vision system positively influences the identification of white quinoa quality.

In [7], a research was carried out where a classification of wheat varieties was made using computer vision, the use of image classification using eFV and CNN algorithms was proposed. To compare the different methods proposed, the accuracy of each of them was evaluated in the evaluation set, which was composed of 195 samples. The result was an accuracy of 95% in the classification of a dataset of seeds of 6 varieties of wheat grain.

In another research [8], an image processing system was developed for the classification of green coffee, which has an inaccurate selection by human personnel and high cost due to the use of machinery, for which an evaluation of the total efficiency of the algorithm was carried out, i.e. the amount of good beans that pass for bad (false rejection), as well as the amount of bad beans that pass for good (false acceptance), obtaining results such as: false rejection 16.7% and false acceptance 7.3%.

The research [9] addressed the problem of rice grains, which present variations in their characteristics in relation to size, cooking consistency, aromatic qualities and grain color, also to identify if the grains have any defects. The OpenUp software methodology was used, making use of MatLab with the Toolbox Image Processing. Reliability results were obtained: 95% for discrimination according to class, 96% for discrimination according to type of defect and 100% for grain count.

The objective of this research is to determine the influence of a mobile computational vision system on the identification of the quality of white quinoa through the evaluation of its level of efficacy, sensitivity and specificity.

II. Methodology

Computational vision can be defined as the processes of obtaining, characterizing and interpreting information from images taken from a tridimensional world [10].

The purpose of this research is to identify the quality of white quinoa through a mobile computer vision system (hereinafter MCVS), being experimental and pre-experimental.

A. Population

Images of white quinoa portions of 5gr. Peru - La Libertad are based on the antecedent Control of grain quality for mobile devices using image processing.

B. Procedure

Here we describe the phases to develop a mobile computational vision system with the objective of identifying the quality of white quinoa, under the Android platform in Java language, using algorithms and functions from the OpenCV and TensorFlow library. This research project is developed under the cascading life cycle.

1) Analysis: To identify the quality of the processed quinoa, we base our analysis on its physical characteristics such as shape, color and size, as indicated in the specifications of the Peruvian Technical Standard (NTP) [6], specified in Table I and Table II, as well as the American Society for Testing and Materials (ASTM).

TABLE I. Criteria for the Classification of Quinoa Grain According to Size

Size of grains	***Average kernel diameter, expressed in mm***	***Mesh***
Extra large	Greater than 2.0	85 % retained on mesh ASTM 10
Large	greater than 1.70 up to 2,0	85 % retained on mesh ASTM 12
Medium	greater than 1.40 up to 1.69	85 % retained on mesh ASTM 14
Small	less than 1.40	85 % passing through mesh ASTM 14

TABLE II. Criteria for the Categorization of Quinoa Grains According to Physical Characteristics - NTP 205.062:2009

Sensory Parameters	***Unit***	***Category 1***	***Category 2***	***Category 3***
Whole grains (A)	%	96	90	86
Broken grains (B)	%	1,5	2,0	3,0
Immature grains (C)	%	0,5	0,7	0,9
Contrasting grains (D)	%	1,0	2,0	2,5
Total impurities (E)	%	0,25	0,30	0,35

Physical characteristics considered for analysis based on the NTP, expressed in Table II. Where graph "A" in Fig. 1 refers to whole kernels, graph "B" to broken kernels, "C" to immature kernels, "D" to contrasting kernels and "E" to impurities.

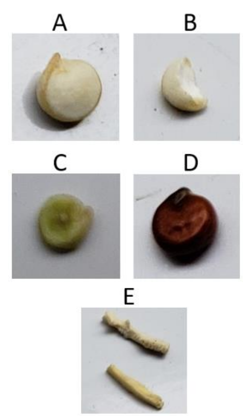

Fig. 1. Physical Characteristics Considered for the Analysis based on the NTP.

C. Design

1) Capture: The following characteristics were taken into account for capture in a controlled environment (Fig. 2):

- Size set at 20cm x 20cm on a white background.
- Resolution: 3024x3024.
- Image color model: RGB.

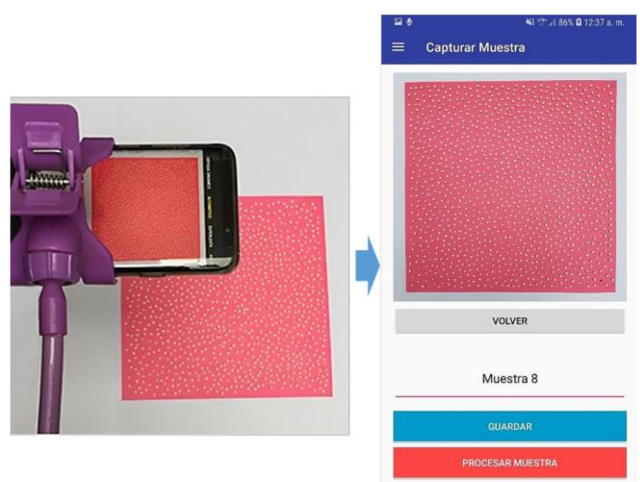

Fig. 2. Sample Capture in a Controlled Environment.

2) Preprocessing: The most suitable technique to smooth the image is the Gaussian low pass filter, because it is the most computationally efficient and smoothes the image better for segmentation.

a) Feature enhancement techniques: The feature enhancement technique used is contour detection, which allows to better highlight the external details of the analyzed elements, for this purpose the Canny algorithm was applied.

b) Morphological operator techniques: The morphological operator technique "closure" is used to eliminate internal noise and the morphological operator "dilation" is used to highlight details.

```
public Mat preprocesamiento(Mat rgba){

    Mat img = rgba.clone();
    Mat normalQuina = new Mat();

    Imgproc.cvtColor(img, normalQuina, Imgproc.COLOR_RGB2HSV);

    org.opencv.core.Size s = new Size( width: 5, height: 5);
    Imgproc.GaussianBlur(normalQuina, normalQuina, s, sigmaX: 0);

    List<Mat> canal = new ArrayList<>();
    Core.split(normalQuina, canal);

    return canal.get(0);
}
```

Fig. 3. Function for the Application of Image Preprocessing.

In Fig. 3, the Gaussian filter was applied and returns image with the first HSV channel.

Detail interface (image preprocessing):

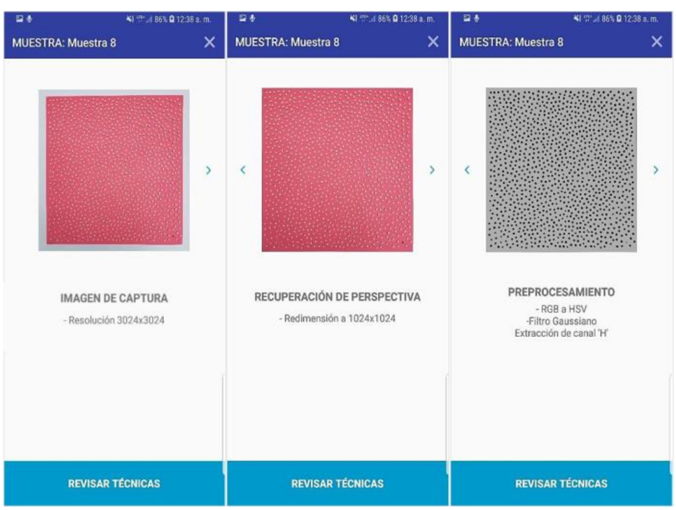

Fig. 4. Image Processing.

3) Segmentation: The segmentation method that best suits our project, is “thresholding”. In Fig. 4, the OpenCV method is applied with the Otsu technique of inverted binarization which allows to calculate the threshold automatically + the morphological operator Cierre to eliminate noise.

4) Description:

a) Feature extraction techniques. Region descriptors are used in this phase, which allow us to extract features such as the area through its pixels in a binarized image free of noise.

b) Region of interest: It is determined that a quinoa grain of extra-large class does not exceed 15.36 pixels, and will always be within the region of interest of 24x24 pixels (Fig. 5).

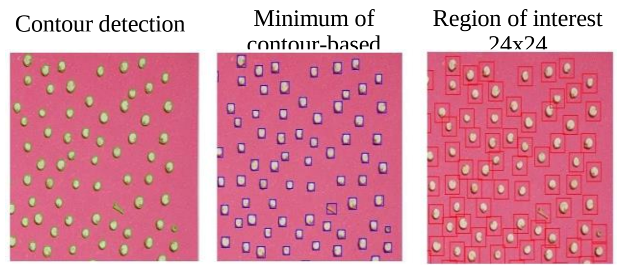

Fig. 5. Feature Extraction.

Detailed interfaces (segmentation and description): Shown in Fig. 6.

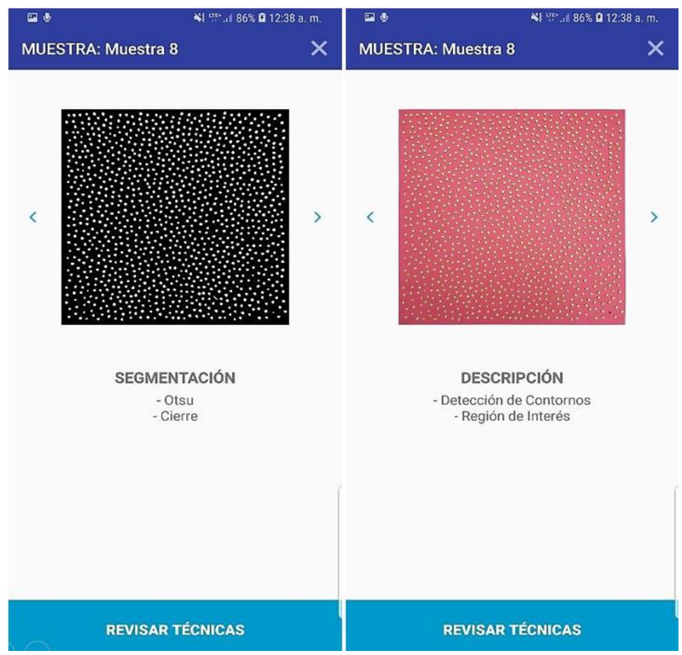

Fig. 6. Segmentation and Description Interface.

5) Recognition: Based on the contours and the region of interest found in the previous phase, in this stage the different types of elements are classified.

a) Classification of elements through convolutional neural network: Specifically a convolutional neural network (CNN).

b) Architecture of the proposed convolutional network: The input is defined with an image of size 224x224 and depth of 3 RGB (Fig. 7), this is received by the input layer causing the pixel to be driven with a neuron reaching 150,528 neurons. In the first hidden layer the regular convolution is specified, from the second hidden layer a deep convolution and a point convolution are rotated, reducing the resolution and increasing the channels. Then the average Pooling is run to reduce the image leaving 1x1x1024. Finally, in the output layer, the Softmax activation function is executed, which returns the probability of the type of element to which the entered image belongs.

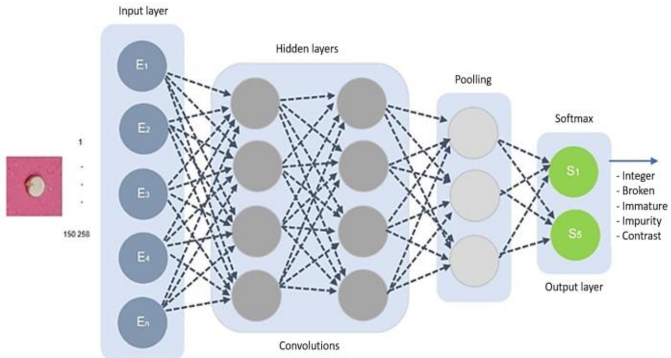

Fig. 7. Architecture of the MobileNet CNN Network Model for Element Classification.

Detailed interfaces (recognition): Shown in Fig. 8.

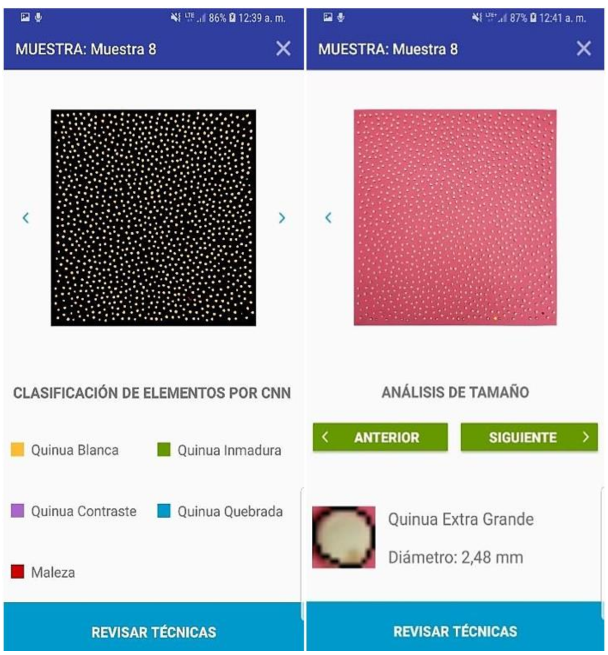

Fig. 8. Recognition Interfaces.

6) Interpretation: With the information obtained in the recognition phase: quantity of elements identified according to their type (whole grains, broken grains, immature grains, impurities and contrasting grains) and the quantity of grains according to their size (extra-large, large, medium and small) according to the standards specified in Tables I and II, the interpretation is performed (Fig. 9).

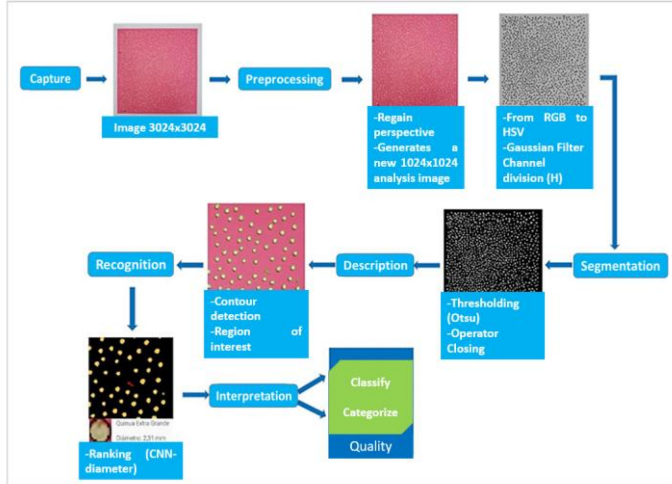

Fig. 9. Architecture of the SVCM in the Identification of White Cinchona Quality.

D. Implementation: for the Implementation of the Mobile Computer Vision System, the following was Considered

1) Technologies used: Android Studio 3.1.3 (IDE), OpenCV 3.4.0 and TensorFlow 1.11.0 (Library), Phyton 3.7.0.

2) Dataset for training: For the training of the network, a set of images is prepared with the different classes of elements to be identified (whole quinoa grains, broken quinoa grains, contrast quinoa grains, immature grains and impurities (weeds).

The following were collected 3000 images with 48x48 resolution, of the five types of elements distributed as follows (Fig. 10):

- 800 whole class images.
- 700 images of broken class.
- 600 contrast class images.
- 500 immature class images.
- 400 weed class images.

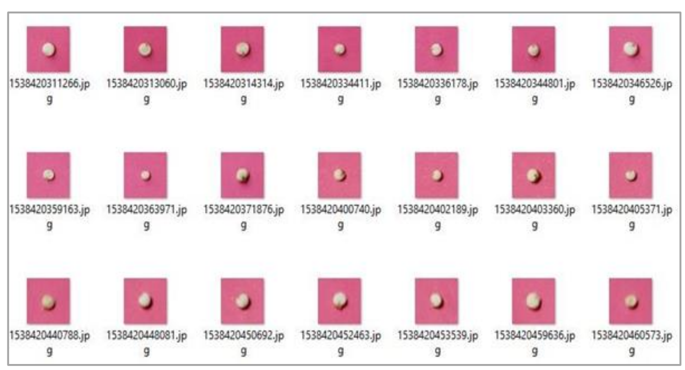

Fig. 10. Images of the Entire Quinoa Class for CNN Network Training.

3) Testing: In this phase, black box testing was performed, to measure the results of our application. Some examples of tests are detailed below:

- Case 1

  Input: 10 grains of extra-large quinoa, 6 grains of large quinoa, 5 grains of medium quinoa, 4 grains of small quinoa (Fig. 11).

  Output:

Fig. 11. Test Results Obtained by Size.

- Case 2:

  Input: A complete sample was loaded into the mobile computer's vision system (Table III) with the following expected result (Fig. 12).

TABLE III. EXPECTED RESULT OF A SAMPLE BASED ON NTP

Criteria Analyzed	**Manual según NTP**		
	Quantity	***Results***	
Total grains analyzed	1191.00		
Small grains	1	0.08%	71.43%
Medium grains	36	3.04%	
Large grains	301	25.44%	
Extra large grains	845	71.43%	
Whole grains	1183	99.33%	Category 1
Broken grains	2	0.17%	Category 1
Contrast grain	2	0.17%	Category 1
Immature grains	2	0.17%	Category 1
Total, impurities	2	0.17%	Category 1
CLASS	**No class**		**71.43%**
CATEGORY	**Category 1**		

Output:

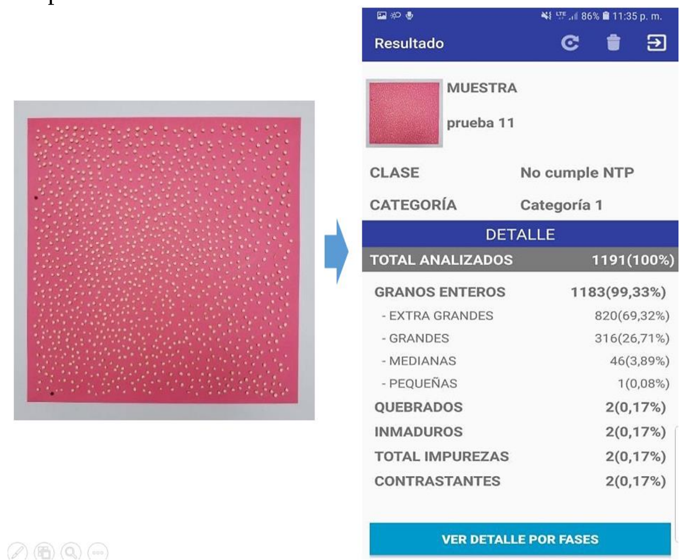

Fig. 12. Results obtained from Testing a Sample based on the NTP.

III. RESULT

For the analysis of the results, 385 samples were used, which were obtained randomly from different types of commercial quinoa, which were evaluated by the manual method based on the Peruvian technical standard using a digital balance and a digital vernier.

For the treatment of the results, a multiclass confusion table analysis was used, for which the following considerations are taken:

- True Positive (TP). When the actual class is correctly classified by the MCVS.
- False Negative (FN). When a real class is classified by the MCVS as another class.
- False Positive (FP). When actual classes are misclassified by MCVS as an evaluated class.
- True Negative (TN). When classes other than an evaluated class the MCVS classifies them as classes other than the evaluated class.

A. Efficacy Analysis

Two aspects are evaluated for our research:

From a total of 385 samples evaluated by the MCVS, 370 correct results (TP) in class prediction have been obtained, reaching an efficiency of:

$$MCVS\ Effectiveness\ (class) = \frac{370}{385}x100 = 96.10\%$$

On the other hand, out of a total of 385 samples when using the S to determine the category, we obtained 373 correct results (TP) in category prediction, reaching an efficiency:

$$MCVS\ Effectiveness\ (category) = \frac{375}{385} x100 = 97.40\%$$

The total efficiency of the MCVS is obtained by applying the arithmetic mean of the two efficiencies:

$$MCVS\ Effectiveness\ (Total) = \frac{96.10 + 97.40}{2} = 96.75\%$$

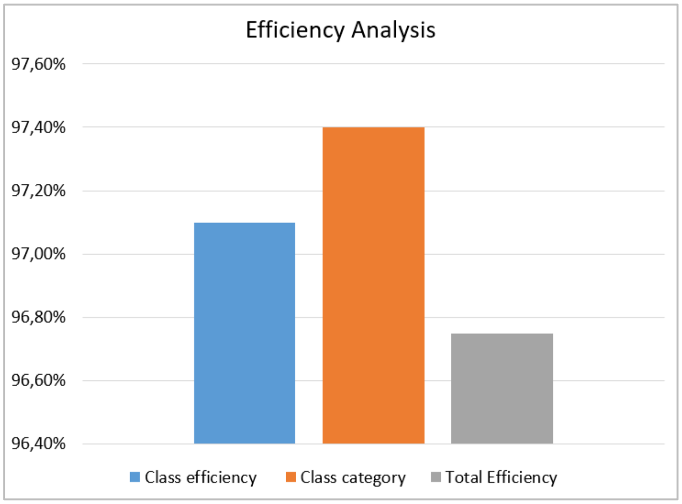

Fig. 13. Efficiency Analysis.

B. Sensitivity Analysis

Sensitivity obtained for the prediction in each class by the MCVS.

$$MCVS\ Sensitivity\ (Total) = \frac{80.58 + 83.52}{2} = 82.05\%$$

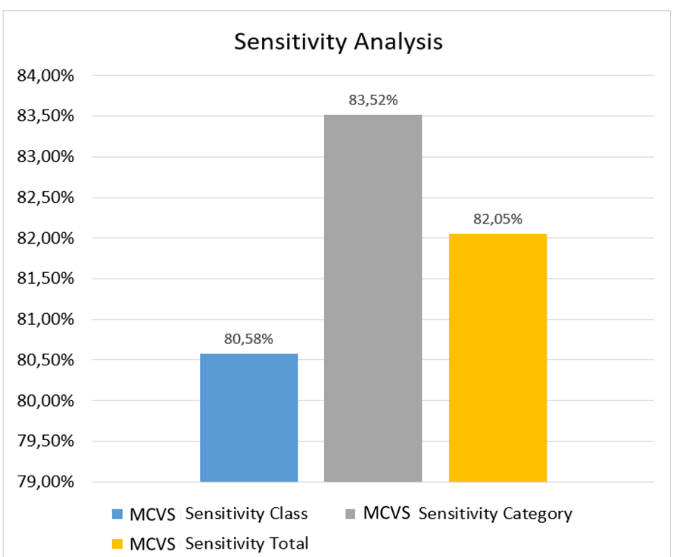

Fig. 14. Result of the Sensitivity Analysis.

C. Percentage of Specificity

Specificity is the percentage that the MCVS predicts an element other than the one evaluated as such. For our research two aspects are evaluated Specificity (class) and Specificity (category). The total specificity of the MCVS is obtained by applying the arithmetic mean to both specificities.

$$MCVS\ Efficiency\ (Total) = \frac{98.90 + 99.32}{2} = 99.11\%$$

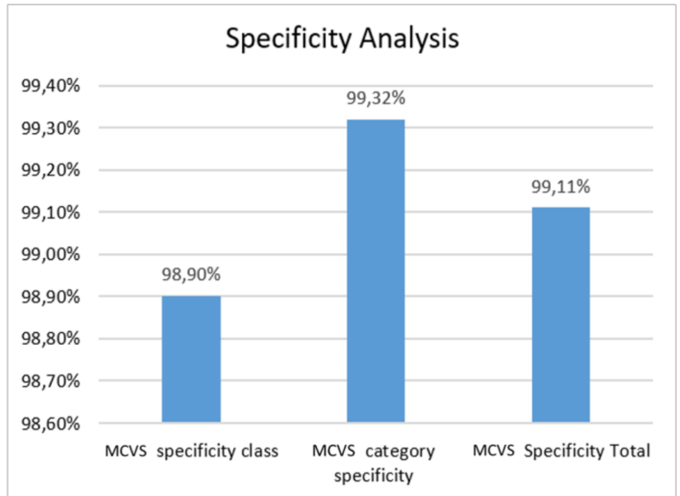

Fig. 15. Specificity Analysis.

IV. Discussion

In the present investigation, it can be stated that the Mobile Computer Vision System has reached an efficiency level of 96.75%, a sensitivity of 82.05% and a specificity of 99.11%. However, the results achieved with processed white quinoa samples were obtained under a controlled environment. For the analysis, only the physical characteristics of the grains, such as shape, color and size specified in the Peruvian technical standard, were considered. With the result it was identified that a quinoa grain of extra-large class does not exceed 15.36 pixels, and will always be within the region of interest of 24x24 pixels.

The finding in the efficiency indicator (Fig. 13) is slightly higher by more than 1% with respect to the previous research carried out in Argentina on the classification of wheat seed by means of computer vision [7], this could be due to the fact that in this research they used a convolutional neural network based on "AlexNet" which has a lower classification accuracy than the "MobileNet" model, in addition, this previous research used only 315 images for the training of its CNN network.

The result of the developed MCVS reaches a sensitivity of 82.05% as shown in Fig. 14, which is 11.40% lower than the research conducted in Peru on pattern recognition for polished rice grain by image processing [9], which evaluated 215 grains for discrimination according to their class and type, being this grain approximately 4 times larger than a quinoa, also for the capture they used as a controlled environment a scanner which provides constant illumination. Therefore, it is suggested for future work to acquire the sample in an environment with constant illumination.

As for the analysis of specificity, it was achieved 99.11% as shown in Fig. 15, surpassing by 8.20% the research conducted in Colombia [8] for the classification of green coffee beans, where they obtained a specificity of 90.91%; this could be due to the fact that this research had to classify among 10 varieties of beans based on different characteristics of color, shape and borer. Therefore, they had to implement classification algorithms for each scenario with dispersed results.

The results for the extra-large class have a sensitivity of 100%, while for the small class 50%, due to the fact that the small grains in the classification by the CNN network are in some cases mistaken for grains of the immature type since they share similar characteristics.

V. Conclusion

With the present research, it was possible to determine the influence of a mobile computer vision system in the identification of the quality of white quinoa, by means of image processing techniques and algorithms.

A mobile computational vision system was developed to identify the quality of white quinoa with a sensitivity level of 82.05%. This is due to the fact that in some cases the CNN network confuses small grains with immature ones, and also in the sample space, due to the number of grains, they are difficult to separate, which complicates their measurement.

Thanks to technological advances for mobile devices, it is now possible to ensure that it is possible to implement robust systems to solve problems by applying computer vision on this platform.

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Radiofrequency Temperature Control System for Fish Capture

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***Abstract*—Artisanal fishing is one of the activities with the greatest economic impact worldwide. In the present research, the radiofrequency temperature monitoring system for fish catches was aimed to determine the influence on the satisfaction of fish catches. The dimensions included were time delay and direct cost; on the other hand, in the monitoring system were usability and reliability. It was shown that the use of the radiofrequency temperature monitoring system decreased the direct cost incurred, reduced the time required to locate hot spots, increased satisfaction and confidence in the system by 95%.**

Keywords*—*Temperature monitoring system; satisfaction; radiofrequency; fish capture

I. Introduction

Artisanal fishing activity plays an important role in food, profit and work occupations in the world. The fishermen who are independent as well as those organized in associations, take the activity as a daily life and use it for their consumption, using small boats and artisanal skills [1]–[3]. In this regard, the current pandemic has hit fisheries hard, especially in the early 2020 [4], which has been evolving favorably, achieving a recovery in recent months [5], but greater attention still needs to be paid to artisanal fishing. From the economic point of view, it produces benefits that symbolize a significant percentage of GDP, basically in developing countries with coastal environments. About 82.1 million jobs in the world are in this activity [6].

Artisanal fishing is currently known as the activity carried out by natural or legal persons operating personally in small boats. In Peru it is known as small-scale fishing. According to the Encuesta Nacional de Hogares (ENAHO) [7], 0.6% of the economically active population belongs to the artisanal fishing activity with 91,937 jobs at the national level, characterized by a high presence in the maritime and continental areas. There are programs for Peruvian artisanal fisheries that are often too expensive and not suitable for multiple ports, and incentives for fishermen to keep logbook reports are very low [8].

The association of artisanal fishermen of Huanchaco was founded on June 3, 1986, and is currently made up of 30 artisanal fishermen whose main work is catching and selling fish. They enter the sea an average of one kilometer out to sea, sailing for hours without having a specific point or place to throw their fishing nets to catch more fish. The “caballito de totora”, oars and fishing nets are the instruments they use for their work; when the tide is high or rough (as they colloquially call the sea waters when the waves are larger than average) they do not enter.

Few fishermen know from empirical knowledge how to determine if the area where they are going for their fishing activity is favorable, because there are fish that tend to be in favorable biophysical environments located in areas where the sea temperature is pleasant for their habitat [9], [10]. But since knowledge is minimal, not all associates have the experience to know which points or places have a high or low temperature index. This generates a problem in terms of loss of time and the direct cost of rowing from one point to another without having at least some help to make a correct decision at the moment of deciding on a favorable capture point. To achieve an adequate catch of fish, it is necessary to apply certain technologies that help the optimal performance [11], both fishing nets and electronic devices should be taken into account to help the rapid location of fish and data collection for better decision making, helping to reduce the unit cost.

II. Related Work

The following studies were considered as background for the radiofrequency wireless temperature monitoring system and fish catch satisfaction:

In the research [12], the objective was to collaborate in the exploration of warming signals, ocean acidification and its impact on marine and coastal ecosystems in the Colombian territory. To achieve this, they analyzed data from different coastal, estuarine and oceanic stations in the period 1993-2011 by Invemar. They showed a long-term average sea temperature increase trend, in the Caribbean at 0.23 °C per decade and in the Pacific Ocean at 0.18 °C per decade. They concluded that continuous changes in sea temperature continue to affect Colombian marine ecosystems.

In [13], the objective of the research was to raise fishermen's awareness of the need to fish correctly without harming the environment. They used the Nahed and Tirado Methodology and semi-structured surveys. The results showed that 30% of the fishermen interviewed spent 5 hours, 25%

spent 4 hours, 25% spent 6 hours, 10% spent 3 hours, 5% spent 8 hours and 5% indicated that it depended on the tide. They concluded that all groups are in favor of better control of their work.

The research is significant in terms of taking the temperature of the sea to show warm spots, which will stimulate people to make the decision to look for the best place to carry out their artisanal fishing activity, generating direct and indirect income to him or his family and by reducing the time the fisherman can perform other activities that will help him to have other economic income.

The research has a positive environmental impact, as it provides the measurement of sea temperature, which will help to make decisions on whether to carry out a possible targeted closure.

III. Methodology

The type of study was pre-experimental; the sample consisted of 30 artisanal fishermen. Data collection was by means of questionnaires.

A. Population

For this research, a total of 30 artisanal fishermen have been considered as a sample, taking into account all the members of the association of artisanal fishermen of Huanchaco, Trujillo.

B. Data Collection

1) Technique: The survey technique was used to obtain the indicators of delay time to locate hot zones, delay time to detect hot zones and direct cost.

2) Data analysis: SPSS was used for quantitative data analysis. It is a powerful tool for data processing and statistical analysis [14].

3) Procedure: The following steps were taken to collect data before using the RF wireless monitoring system:

a) Observation: A meeting was held with the fishermen at accessible times so as not to interfere with their work, and each fisherman took an average of 5 minutes per person to complete the questionnaire. The questionnaire consisted of a total of 7 questions related to fishing activities, where the grade range was A - D, where "A" is excellent and "D" is very deficient.

b) Sorting: The information was then sorted by means of dynamic tables in Excel.

C. Monitoring System Simulation

A complete circuit of the monitoring system was made in Proteus, software that we used mainly to test (simulate) our measurement node, which consists of a microcontroller (ATMega328P) [15], DS18B20 temperature sensor that communicates digitally with the terminals Vcc, GND and the Data pin [16], GSM module SIM800F which was connected to the TX and RX pins [17], for transmission and reception, capacitor and quartz crystal.

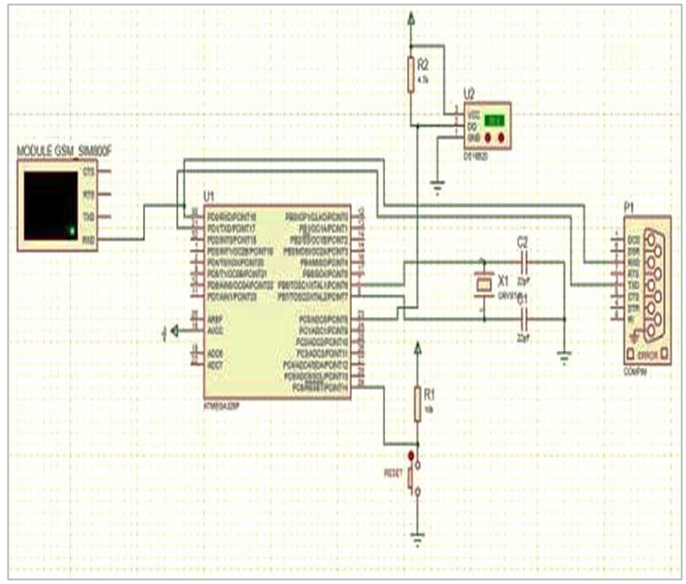

Fig. 1. Complete System Circuit in Proteus.

Fig. 1 shows the terminal where the AT commands appear, executing one after the other to send the temperature obtained by the temperature sensor, this data is sent in JSON format.

D. Development of the Mobile Application

The Mobile-D methodology was used, which has a mixture of many techniques and best practices to aid in the development of mobile applications [18], consisting of five phases: exploration, initialization, production, stabilization and testing.

1) Exploration and Initialization Phase:

Analysis of initial requirements.

- Display a mapping of warm zones.
- Display Temperature.
- List the possible fishes in the area.

2) Production: Implementation of the functionality to list the buoys and identification of zones by temperature through the heat gradient, then the implementation of the functionality to show the possible fish that may appear in the previously identified zones.

3) Stabilization: A refactoring of the functionality of listing (buoys and idenified zones) and displaying possible fish that may appear in the color zones established by their temperature.

4) Tests: An evaluation of the wireless monitoring system with radiofrequency is carried out, performing the heat map visualization test with internet connection, fish visualization, in an interval of 6 days to later give way to the analysis of the results obtained by means of the post-test examination.

a) Listing of buoys: The data from the database are correctly displayed, making the list of buoys, shown in Fig. 2.

Fig. 2. Buoy Listing Interface.

b) Heat map: The heat map of the correctly selected buoy is displayed, showing the buoy in the sea with colors with respect to the thermometer, shown in Fig. 3.

c) Display possible fish: Possible fish that are close to the selected buoy are correctly displayed next to the temperature map, as shown in Fig. 3.

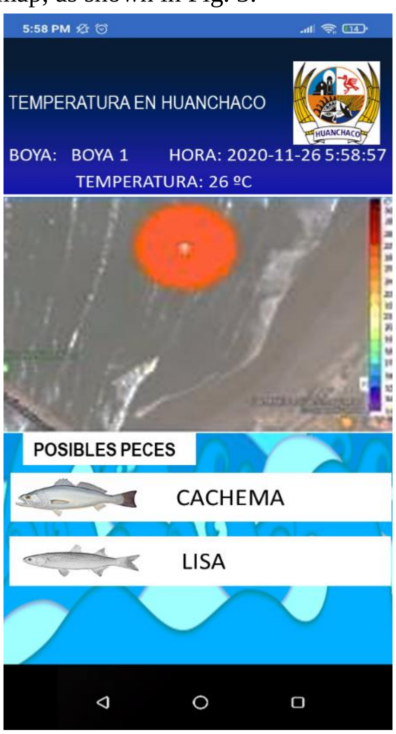

Fig. 3. Heat Map Interface and Fish Listing.

d) Temperature history: The average daily temperature of the selected buoy for the week is correctly displayed (Fig. 4)

Fig. 4. Week Average Temperature.

IV. Result

The graphs are shown based on the average result, obtained from the Pre and Post implementation tests of the radio frequency temperature monitoring system on fish catch satisfaction for the artisanal fishermen's association, shown in the statistical graph in Fig. 5.

The descriptive results of the general comparison of satisfaction with fish catch. In the pre-test a value of 58% was obtained, while in the post-test it was 83% as can be seen in Fig. 6; this indicates a great difference before and after the implementation of the system.

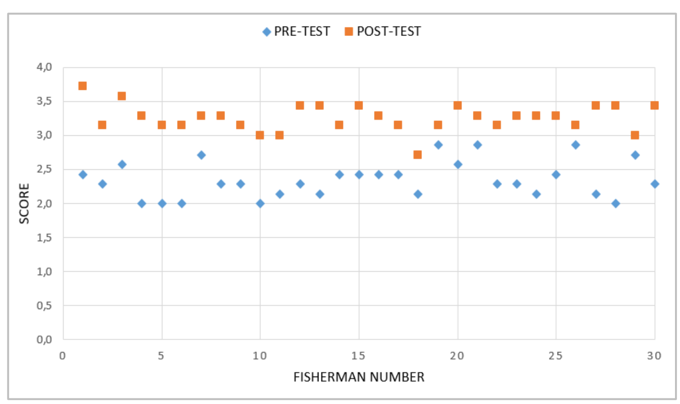

Fig. 5. Overall Comparison of the Pre-Test and Post-Test Satisfaction Results of the Artisanal Fishermen Questionnaire.

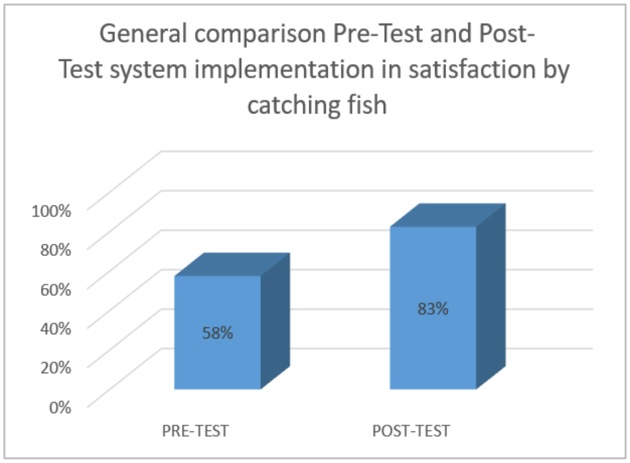

Fig. 6. General Comparison Pre-Test and Post-Test Implementation of the Temperature Monitoring System with Radiofrequency in the Satisfaction of Catching Fish.

Additionally, an in-depth analysis of the results was performed by means of Wilcoxon's W test [18]. Nonparametric statistical methods are useful when there are directional differences.

A. Result based on Satisfaction

When the tests were conducted, the following data shown in Fig. 7 were collected, being the results obtained in the Pre and Post Test based on satisfaction after the implementation of the RF monitoring system according to the score obtained in certain numbers of fishermen.

Subsequently, the Wilcoxon W statistic was used for the study and comparison of related samples to find the level of confidence in the satisfaction with fish capture.

The summary processed in SPSS is shown in Table I.

As can be seen, the Wilcoxon W statistic was -4.7200 and the p value (asymptotic sig. (bilateral)) is 0.000 (less than 0.05), so the null hypothesis is rejected and it is concluded that there is sufficient evidence to affirm that the proposed monitoring system improves fish catch satisfaction with a confidence level of 95%.

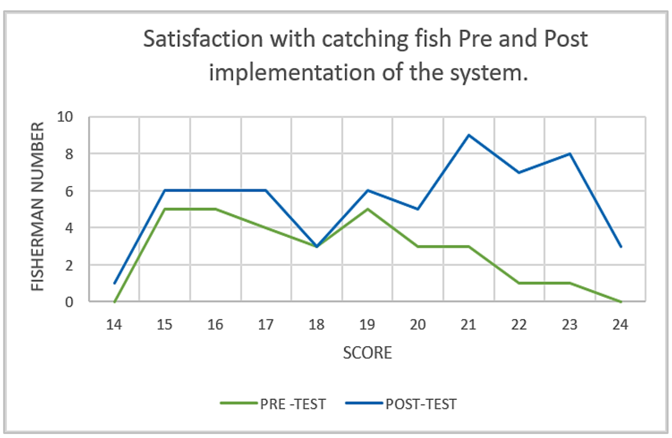

Fig. 7. Pre vs. Post about Satisfaction with Catching Fish.

TABLE I. WILCOXON W TEST (CALCULATED IN SPSS) - SATISFACTION

Ranges				
		N	**Average range**	**Sum of range**
Total POST – Total PRE	Negative ranges	0^a	,00	,00
	Positive range	29^b	15,00	435,00
	Ties	1^c		
	Total	30		
a. Total POST < Total PRE				
b. Total POST >Total PRE				
c. Total POST = Total PRE				
Test Statistics[a]				
		Total POST – Total PRE		
Z		-4,720[b]		
Asymptotic sig. (bilateral)		,000		
a. Wilcoxon signed-rank test.				
a. It is based on negative ranges.				

B. Results based on Delay Time

When the tests were conducted, the following data shown in Fig. 8 were collected, being the results obtained in the Pre and Post Implementation Test of the radiofrequency monitoring system according to the score obtained in certain amounts of fishermen, based on the location of hot zones for catching fish.

Wilcoxon's W statistic was used for the study and comparison of related samples to find the time delay for the location of hot spots.

Subsequently, the Wilcoxon W statistic was used for the study and comparison of related samples to find the delay time for the location of hot zones.

The summary processed in SPSS is shown in Table II.

As can be seen, the Wilcoxon W statistic was -4.683 and the p value (asymptotic sig. (bilateral)) is 0.000 (less than 0.05), so the null hypothesis is rejected and it is concluded that there is sufficient evidence to affirm that the use of the proposed monitoring system had a positive influence on the time delay for fish catching for the fishermen's association, with a confidence level of 95%.

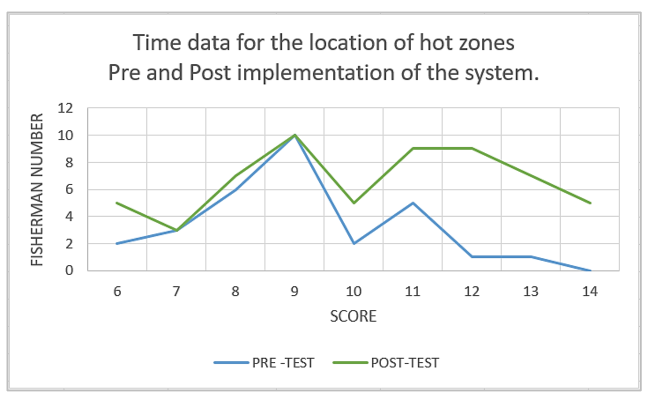

Fig. 8. Pre vs. Post about the Time Data for the Location of Hot Zones.

TABLE II. WILCOXON W TEST (CALCULATED IN SPSS) - TIME FOR THE LOCATION OF HOT SPOTS

Ranges				
		N	**Average range**	**Sum of range**
Total POST – Total PRE	Negative ranges	1^a	2,00	2,00
	Positive range	28^b	15,46	433,00
	Ties	1^c		
	Total	30		
a. Total 1 POST < Total 1 PRE				
b. Total 1 POST >Total 1 PRE				
c. Total 1 POST = Total 1 PRE				
Test Statistics[a]				
		Total POST – Total PRE		
Z		-4,683[b]		
Asymptotic sig. (bilateral)		,000		
a. Wilcoxon signed-rank test.				
a. It is based on negative ranges.				

C. Results based on Direct Cost

When the tests were conducted, the following data shown in Fig. 9 were collected, being the results obtained in the Pre and Post Implementation Test of the radio frequency monitoring system according to the score obtained in certain quantities of fishermen, based on the direct cost incurred by the fish catch for the fishermen's association.

Subsequently, the Wilcoxon W statistic was used for the study and comparison of related samples to find the direct cost.

The summary processed in SPSS is shown in Table III.

As can be seen, the Wilcoxon W statistic was -3.987 and the p value (asymptotic sig. (bilateral)) is 0.000 (less than 0.05), so the null hypothesis is rejected and it is concluded that there is sufficient evidence to affirm that the proposed monitoring system improves the average direct cost incurred by the fishermen of the fishermen's association, with a confidence level of 95%.

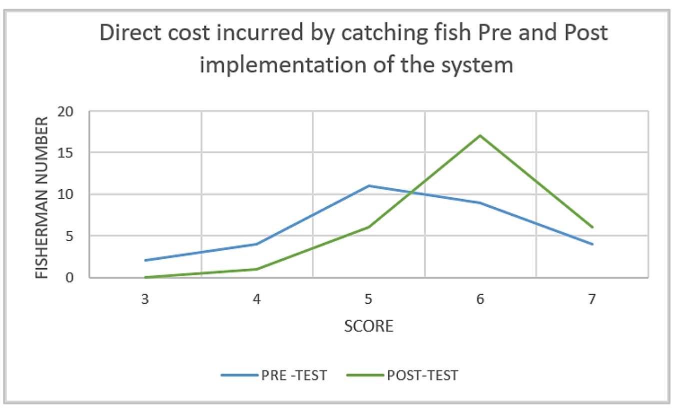

Fig. 9. Pre vs. Post about the Direct Cost Incurred by Catching Fish.

TABLE III. WILCOXON W TEST (CALCULATED IN SPSS) - DIRECT COST

Ranges				
		N	**Average range**	**Sum of range**
Total POST – Total PRE	Negative ranges	0^a	,00	,00
	Positive range	19^b	10,00	190,00
	Ties	11^c		
	Total	30		
a. Total 2 POST < Total 2 PRE				
b. Total 2 POST >Total 2 PRE				
c. Total 2 POST = Total 2 PRE				
Test Statistics[a]				
		Total POST – Total PRE		
Z		-3,987[b]		
Asymptotic sig. (bilateral)		,000		
a. Wilcoxon signed-rank test.				
a. It is based on negative ranges.				

V. DISCUSSION AND CONCLUSION

The influence of the temperature monitoring system with radiofrequency in the satisfaction of catching for the Huanchaco artisanal fishermen's association according to the established index is reflected favorably according to Fig. 5.

The results obtained from the pre- and post-implementation tests of the radiofrequency temperature monitoring system on fish catch satisfaction for the Huanchaco artisanal fishermen's association (Fig. 6 to 9) were relevant for the development of this research.

The use of the temperature monitoring system with radiofrequency in the satisfaction of catching fish had a positive influence.

In Fig. 7, it can be seen that 29 fishermen out of a total sample of 30 are in the positive range, which shows that the use of a radiofrequency temperature monitoring system positively influences fish catch satisfaction.

It was demonstrated that the use of temperature monitoring system with radiofrequency in the satisfaction of catching fish. The result (Fig. 8) shows that 28 fishermen out of a total sample of 30 are in the positive range of the Wilcoxon test, thus demonstrating that the use of a radiofrequency temperature monitoring system has a positive effect on the delay time for the location of hot zones.

It was demonstrated that the use of the temperature monitoring system with radiofrequency decreased the direct cost incurred. The result (Fig. 9) shows that 19 fishermen out of a total sample of 30 are in the positive range of the Wilcoxon test, thus demonstrating that the use of a radiofrequency temperature monitoring system reduced the direct cost incurred by the fishermen's association.

The analysis of the results showed that the use of the radiofrequency temperature monitoring system reduced the time required to locate hot zones for 28 fishermen, reduced the direct cost for 19 fishermen, and increased satisfaction and confidence in the system by 95%.

The research has allowed the integration of radiofrequency that so far has tried to address the problems of artisanal fishermen in their work. The conclusions of this research allow the decision making of the artisanal fisherman for his fish catching process.

VI. Recommendation

In a research project as interesting as this one, it is desirable to improve it; therefore, it is recommended to future students or researchers who are interested in our research project, the implementation of more interactive interfaces to help the user, as well as to accelerate the data collection process. It is important to take into account that more studies related to the improvement of the work in artisanal fishing should be carried out, since there are many problems that afflict this small sector.

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Ontology based Semantic Query Expansion for Searching Queries in Programming Domain

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***Abstract*—Information on the web is growing rapidly; learning programming languages has become one of the most widely searched topics. Programmers and people of several backgrounds are now using Web search engines to acquire programming information, including information about a specific language or topic. Nonetheless, due to a lack of programming knowledge, many laypeople have difficulties in forming appropriate queries to articulate their inquiries, so they used to write short queries, which leads to vocabulary problems and contextless query. Besides, semantics is almost neglected in traditional search query since it is just keyword-based searches, which deem their search to be imprecise with irrelevant results, due to the use of unclear keywords. A Semantic query expansion method is proposed for disambiguating queries in computer programming domain using ontology. The integration of Cosine similarity method into the proposed model improved the expanded query, and accordingly, the searching results. The proposed system has been tested with several ambiguous and misspelled queries and the generated extensions proved to retrieve more relevant results, when applied to a search engine. The quality of the retrieved results for the expanded queries, are much higher than that for the crude queries. The proposed technique was implemented, and then tested with external independent testers. They confirmed the mechanical test results and displayed its improvement with an average of precision @10 82.2% and 91.1% respectively. The results were promising and therefore open further research directions.**

Keywords—Query expansion; ontology; semantic search; short queries; cosine similarity

I. Introduction

There is a massive amount of data available on the web, and it is growing, freely, by the seconds. Yet, this free information-growth has not been assessed by a reliable information retrieval tool. A large percentage of the results obtained from web-search engines are not satisfactory relevant results. The main reasons for this defect are the lack of searcher's knowledge, the usage of short queries, and the intrinsic complexity of forming appropriate queries. These challenges lead to ambiguous queries, and accordingly, the retrieval of irrelevant results. Surveys indicate that almost ***25%*** of web searchers are, in most cases, unable to find useful results in the first set of URLs that was retrieved by the search engine [1].

It is not always easy to specify the needed information using exact query terms, because of the vocabulary problem. This problem became even harder due to polysemy and synonymy [2].

To obtain more relevant documents, queries must be disambiguated by looking at their context. Query expansion techniques were employed to overcome some types of these ambiguities. These techniques range from employing relevance feedback mechanisms, to, the utilization of knowledge base models, such as ontologies to resolve ambiguities [3].

Some of the search engines have employed query refinement methods to address short query problems. The idea is that, whenever a query is ambiguous or misspelled, the search engine suggests, to the user, some more refined, narrowed and less ambiguous queries. This method, however, suffers from several limitations and shortcomings [4]. First, selecting and retrying these refined queries induced significant additional difficulties and load upon the user. Second, since these refined queries are, usually queries that were submitted by other users in the search log, it most properly, would not reflect his intended searching objective. Third, such refined queries are not utilized to generate or improve the final results presented to the user, and hence do not lead to perceive improvement in the new search results list. Finally, the refined queries, as such, are obtained by keyword matching against the original short query, and thus are unrelated in meaning, or still very ambiguous. The user would have to face many longer but unrelated queries. Therefore, with these presented limitations, the authors propose a system aimed at reducing end users' efforts and tolerating their errors, by expanding their query into a prespecified domain. The specified domain knowledge is extracted from knowledge base.

The proposed approach disambiguated queries and related data retrieval by generating a semantic formulation for the query in the selected domain. This system works as both ontology-based query converter and text-based search engine.

The objective of the presented system is to expand short and vague queries using ontology. The ontology language used in the proposed system is based on the Resource Description Framework (RDF) structure, which is written in eXtensible Markup Language (XML) [5]. To expand vague queries in a prespecified domain, ontological terms are to be extracted from a predefined vocabulary of the specified domain.

This paper is structured as follows: Section 2, presents related work, Section 3 discusses Query Expansion, Section 4, describes the proposed system, named Ob-SQE, Section 5, demonstrates system design and implementation, Section 6 evaluates the system. Section 7 displays results and discussion. Finally, conclusions are presented in Section 8.

II. Related Work

There is a great deal of work that has been accomplished by researchers in the field of query expansion. Most of them rely on external sources to provide support for query expansion. Some of those resources are syntactic and others are semantic. QE, often, bridges the vocabulary gaps between queries and web resources [6].

B. Sun et. al., [4] presented a method for refining short queries. They used query retrieval models that construct related multiple derived queries for the user's query. They ranked each of the derived queries according to its similarity to the user's query. This method is useful for improving query refinement and constructing the final results.

H. Imran et. al., [7] constructed thesaurus as a help tool for, semantically, selecting related terms to expand a given query.

J. Sarmah et. Al., [8] developed a system for retrieving Assamase unstructured documents from digital libraries. They used Assamase WordNet and query expansion techniques, to extend the user's original query.

R. Khan et al., [9] proposed a novel approach for the query expansion using WordNet and ConceptNet, which discarded the less important words from the query semantic space.

H. Tran [10] provided a method to match a company's human resources with job assignments received from clients. The author used ontologies as a solution to implement a query augmentation that improved the defining of the context by adding suggestions of relevant words.

S. Rajasurya et al., [11], developed a semantic search engine in the University domain. The authors used ontology as a knowledge base for the information retrieval. It was one layer above a search engine that retrieves more relevant results by analyzing just the keywords.

B. Al-Khateeb et al., [12], proposed enhanced system to expand the user's query using WordNet and generate a list of queries. The best result was, then, selected and retrieved to the user.

Based on the above related work, the usage of WordNet in query expansion is still poor for domain specific because it aims at covering general English words. That is to say, it is mainly language relation rather than semantic or context relation.

Utilization of ontology and semantic are obvious answer for establishing a successful and viable query expansion process, whereas semantic web provides tools and languages to facilitate machine readable access to ontology, such as RDF and Web Ontology Language (OWL).

III. Query Expansion

Query Expansion (QE) also known as query augmentation, is the task of adding new meaningful terms to the original query to increase the number of relevant retrieved documents. The significant problem of query expansion is the choice of the expansion keywords. Terms that are similar and relevant to query terms are usually considered as good terms for expansion. The process of adding terms can either be manual, automatic or user assisted. Manual query expansion relies on user expertise to make decisions on which terms to include in the new query. In the case of automatic query expansion, weights are calculated for all terms and the terms which have the highest weight are added to the initial query. With user-assisted query expansion, the system generates a set of possible query expansion terms for the user to select from [3].

Several semantic QE approaches are available, including linguistic, ontology-based and mixed mode, for addressing the vocabulary mismatch problem [13]. The main advantage of semantic QE using the ontology domain is that the knowledge structure is always available in the expansion mechanism, which clarifies the context of the query. Therefore, it was adopted in the proposed system to expand vague queries.

In this semantic QE, the query term is expanded with super categories in the knowledge hierarchy, then the expanded terms are processed by search engines in a Boolean way using *AND* operator.

The main shortcoming of using ontology as a QE approach is that it relies on exact matching between the query and the ontology vocabulary, which is a complex task for user queries that are written in natural language. To overcome this shortage, techniques are used to measure the similarity to decide which term or expression from ontology is the closest to the user's query.

IV. Proposed System

The proposed solution is an Ontology-based Semantic Query Expansion (Ob-SQE) system which is an assistance tool for crude searchers. It facilitates end user's searching process in obtaining their intended information in a specific domain. Ob-SQE is an ontology-based Information Retrieval (IR) system that employs ontology and semantic knowledge to expand the short and/or vague queries. Therefore, increases the chances of the search engine to retrieve true positive and relevant results. Ob-SQE system facilitates the searching tasks for Internet users, by targeting the search onto specific domain, and expanding the search query to be significant and relevant to that domain of interest.

The Ob-SQE system is not intended to change the current keyword-based search, but rather, strengthen it by supplements keyword from the relevant context domain.

A. Modeling the Ontology Domain

Fig. 1 illustrates the main steps of generating ontology for a given domain. In which, the concepts in the domain are identified, organized and represented & evaluated.

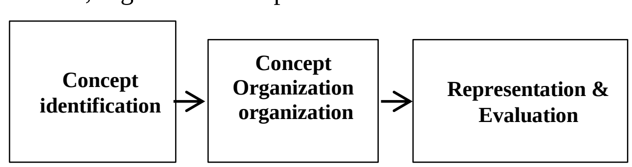

Fig. 1. Summary of Development Ontology.

- Concept identification: Identifies the domain and prepares a list of possible concepts to be included in the domain ontology. A manual mechanism was applied to extract the domain terms from various online resources [14, 15]. The concepts employed in ontology are those core concepts of the domain of interest.
- Concept organization: Determines the key concepts, such as the upper-level concept and the commonly used concepts in this field, in order to establish the core concept sets. Then, it defines the relations and assigns them to concepts, which are usually, "is-a" relations. The ontology organized the domain items into a hierarchical tree, in which nodes of the ontology are concept words, and the edge is the relationship between ontology concepts. Moreover, it selects the top-down structure approach to be utilized to be consistent with the format in which information was provided in the original resources.
- Representation & Evaluation: The generated concepts are organized into the ontology representation using editor and be adopted for defining classes and class hierarchy. The ontology class hierarchy demonstrates the relationships between upper-level and lower-level classes. The type of the created ontology is Light-weight Ontology, which is hierarchical or classificatory. It was selected because a light-weight Ontology does not include too many or too complicated relationships [16]. Then evaluating the consistency and checking the correctness and validity of the generated ontology using the system reasoning to be sure that ontology does not allow any contradictions.

The ontologies (for exercising the proposed system) were developed using the Protégé editor in OWL/RDF to define classes and class hierarchy. There are two created ontologies; one of them covered Java 2 Standard Edition (J2SE) to be used as a context for learning Java Programming and another for learning Python Programming, the user can use them interchangeably. The system is designed for multiple courses with multiple ontologies.

B. System Architecture

Fig. 2 illustrates the architecture and the processes involved in the proposed model, each of which is described in the following subsections.

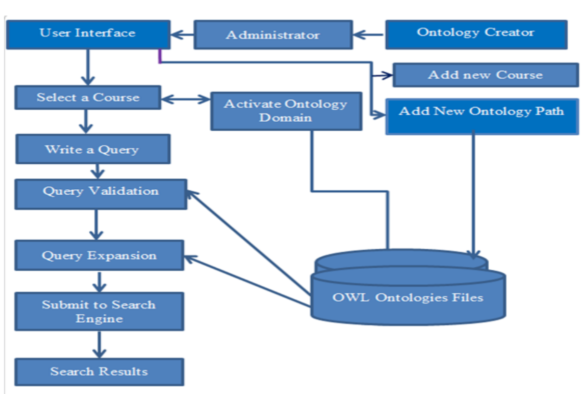

Fig. 2. Architecture of the Proposed System.

To enrich the learning process in general (as this system is portable for any domain topic assuming the availability of the domain ontology), the system architecture and the designed processes were presented as such to help the remotely learning individuals.

The first stage for creating a course is to Modeling the Ontology for the Domain of Interest. The ontologies were developed using the Protégé editor in OWL/RDF to define classes and class hierarchy. There are two created ontologies; one of them covered Java 2 Standard Edition (J2SE) to be used as a context for learning Java Programming and another for learning Python Programming, the user can use them interchangeably. The system is designed for multiple courses with multiple ontologies. The processes involved in the system design are:

1) Creating new course: The administrator can create a new course by adding a new course name and adding a newly created ontology path to these course concepts.

2) Course selection: Through this layer, the user select a course, which invokes and activates the corresponding ontology knowledge base. The user, may then, type a query to be searched.

3) Query validation: In this layer, the query is processed for validation and is utilized to extract a matched ontology term with the user's query. This stage performs the following tasks:

a) Check for a non-empty query.

b) Validate the search query to match ontology classes prior to the expansion phase to guarantee that the query belongs to or close to the domain of interest using a similarity method. An error message is invoked for invalid queries.

c) Cosine similarity method was adopted to measure the highest, syntactically similar key word. This step is to overcome the exact matching to ontology concepts and misspelling problems.

d) Keep the matched term with ontology terms if it does exist.

Result from this phase is, either, the matched concept with the highest similarity, or, a displayed error message.

4) Expanding the query: It provides the semantic for initial query concept by adding new related terms from knowledge ontology files. Expanding process starts with a specific matched term as a bottom-up direction on one path to obtain all super direct and indirect classes to be concatenated together by AND operator [17]. Moreover, it adds any available synonyms for the concept. Synonymy means that concepts are equivalent with the matched term. Consequently the context of the searched concept is determined by an extracted set of, directly and indirectly, linked concepts (in the ontology) by explicit relations including synonyms.

5) Applying the extended query: The expanded query is to be utilized and redirected to Google search engine to obtain the results of its semantic search. Thereafter, the list of the obtained web pages is retrieved to the user.

V. System Design and Implementation for the *Ob-SQE* Model

The proposed system was designed and implemented into the model prototype Ob-SQE as demonstrated in Fig. 3.

The implementation was performed by creating and executing web applications using 'JavaServer Faces' (JSF) as a GUI, and OWL API as a semantic web tool. It is capable of reading, writing, and processing data in domain ontology, via Java programming language within Eclipse editor. The system used the JSF API, to capture and process user's query through user's interface.

For the purpose of this article, the knowledge Ontology of two selected different programming languages were generated to be utilized in the Ob-SQE system, namely, Java 2 Standard Edition (J2SE) and Python Programming.

A. Running Example

This section presents a running example to illustrate the processes involved in the system components, including the creation of new course, query expansion and searching of a vague misspelled query.

1) Create new courses: The system administrator is responsible for creating new courses, by adding their Ontology knowledge file and its path to the system. The paths, files and course name are validated, and an error message is invoked for any inconsistencies.

2) Searching the domain terms: The implemented system is executed through the GUI interface. The following is a typical scenario for an execution session:

a) The user chooses a specific course, say, a Java Course.

b) According to his selection, course ontology will be activated by the system implicitly.

c) A user writes the query "Publik", through the GUI interface. Scenario of a contextual reformulation is applied by a system based on similarity.

d) The query is validated, the matching term "Public", is obtained.

e) OWL's method is applied to search the ontology for related terms with matched term. The matched terms were: "Modifiers", "Access Modifiers" and "Java Programing".

f) The verified query was expanded by combining the matched term with its related terms using AND operator obtaining the logical formula "Public AND Modifiers AND Access Modifiers AND Java Programing."

g) The expanded query was applied to Google search engine.

h) The retrieved websites were displayed for the user.

Fig. 4, illustrates the semantic context of the 'Public' concept as a Java term, which is formed by the concepts 'Modifiers', 'Access Modifiers' and 'Java Programing', (all of them are super classes (hypernyms) for the concept 'Public').

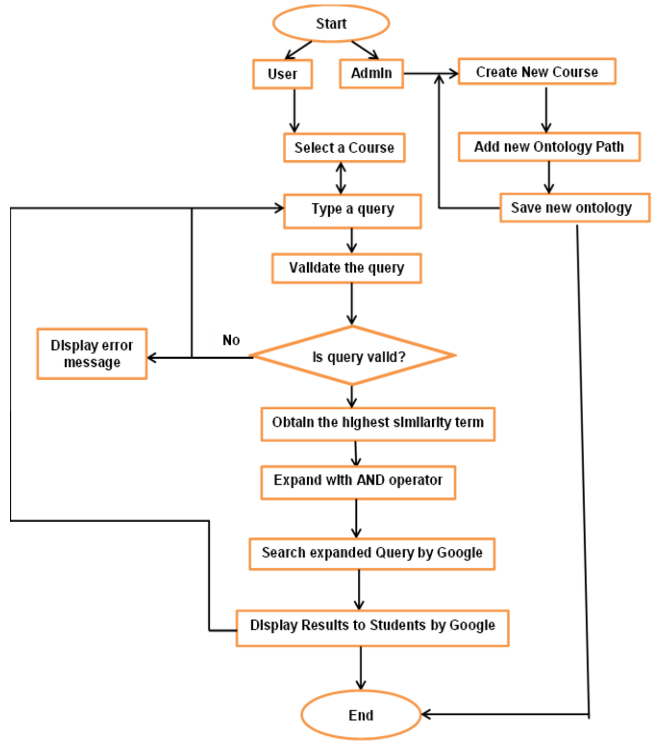

Fig. 3. The Flowchart of *Ob-SQE* Model.

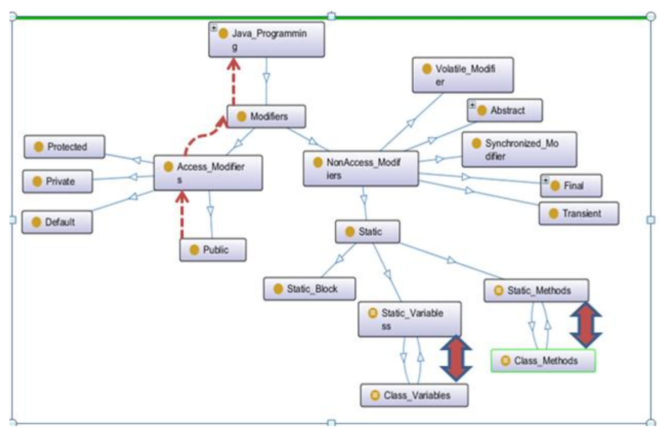

Fig. 4. Semantic Context of Java Concept 'Public'.

In addition, based on the ontology, if the searched concept has synonyms, the system will generate it. For example, Class Methods AND Static Methods are equivalent concepts, so whenever one of them is in the matched list, the other is added to as well. The bidirectional arrows near the bottom of Fig. 4 illustrate two of the equivalent concepts.

Fig. 5 illustrates the semantic context When the query term 'deque' is typed while the Python ontology Knowledge is active, it will be expanded through the super classes with AND operator to be:

"Deque AND Collections AND Python Programming".

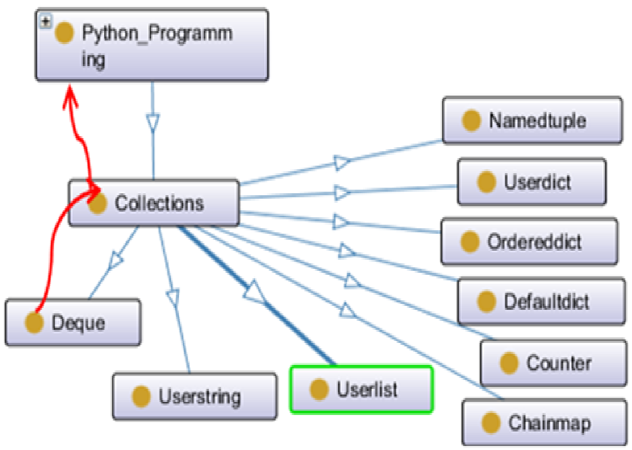

Fig. 5. Semantic Context of the Python Concept 'Deque'.

B. Similarity Method

Given a query and a set of documents, a traditional information retrieval model usually measures the similarity of a query and different documents, and then returns the documents with top-ranked similarities as the results. The Vector space Model (VSM), introduced by Z. Jian, [18], however, represented documents through the words that they are contained. In this model, a query and a set of terms from the ontology knowledge base- each is regarded as set of points (substrings) in the vector space. Every set of points represents a vector. The similarity between the query and the ontology term is realized by the cosine of the angle between these two vectors. The smaller is angle, the greater is similarity. Given two vectors A and B , Cosine similarity is computed using (1).

$$\text{COS}(\theta) = \frac{\sum_{i=1}^{n} ai*bi}{\sqrt{\sum_{i=0}^{n} a_i^2}\sqrt{\sum_{i=0}^{n} b_i^2}} \quad (1)$$

Where: a_i and b_i are the count of the ith substring occurred in the first and second string, respectively.

VI. System Evaluation

A cut -off value of the first 10 results in search engine retrieval effectiveness tests seems reasonable, because search engine users, in most cases, only consider the first page of the retrieved results (usually displaying 10 organic results) [19].

Based on this observation, the effectiveness of the system was evaluated by comparing the average of fitness function and the precision of the top ranked ten results, retrieved by the Google search engine for a given query, and that of its expansion through the application of *Ob-SQE* system. This comparison experiment was repeated for several sets of queries. The system was, also, manually, exercised for evaluation by two external independent users.

A. Fitness Function (F.F)

Fitness function evaluates the quality of the results obtained from Google search engine for the queries before and after the application of the *Ob-SQE* system. The retrieved URLs are tested for judgment using a modified version of Al-Khateeb et al., [13] technique. Name, Title and the Description of each of the retrieved URL is extracted for calculating the similarity and recording the fitness score for the corresponding URL. The similarity (between each retrieved URL contents and user query) was computed using (1), whereas the fitness score was calculated using (2).

$$\text{Fitness} = A \times \text{Order} + B \times \text{Sim1} + C \times \text{Sim2} + D \times \text{Sim3} \quad (2)$$

Where: *Order* is the order of the returned results, *Sim1*, Sim2 and *sim3* are the Jaccard similarity between the query and the URL-Name, URL-Description and URL-Title, respectively. *A, B, C* and *D* are factors representing the degree of importance. *A=0.1, B=0.2, C=0.3 and D=0.4* .

$$\text{Jaccard\_similarity}(S1, S2) = |S1 \cap S2| / |S1 \cup S2| \quad (3)$$

Where: *S1*and *S2* are the two strings considered for similarity.

Equation (4) computes the average of fitness for top ten ranked results.

$$\text{Average of Fitness} = \frac{\sum_{i=1}^{10} Fitness}{n} \quad (4)$$

B. Precision @ K

Precision is the proportion of retrieved documents that were relevant. Whereas Precision @ K is the proportion of the top-*K* documents that were relevant [20].

The four steps to compute Precision @*K* are:

1) Set a rank threshold *K.*

2) Compute the percentage of relevance in top *K.*

3) Ignore documents ranked lower than *K.*

4) Finally, compute the average of *P@K* for every query using (5).

$$\text{Average of P@K} = \frac{\sum_{1}^{k} p@k}{R} \quad (5)$$

Where *k* is the rank of each relevant document, *R* is a total number of relevant documents and *p@k* is the precision of the top-k retrieved documents [21].

C. System Evaluation

The system was evaluated by the application of the Average Fitness Function and Precision @K, for results retrieved from searching for a crude/initial query and that of its extension.

A prepared sample of queries from Java programming language was utilized to measure the effectiveness and accuracy of the system. Each query was expanded through *Ob-SQE* system. For each couple of queries (the query and its expansion) Google search engine was, then, invoked twice to search for the original crude query and its expanded version. The retrieved URLs for the original and the expanded queries were analyzed to obtain the averages of precision and the averages of fitness for the two set of results. Table I, demonstrates the average of precision and the average of fitness function of each query before and after expanding it through the *Ob-SQE* system.

TABLE I. THE RETRIEVAL ACCURACY OF GOOGLE SEARCH ENGINE BEFORE AND AFTER THE EXPANSION PROCESS (OB-SQE SYSTEM) FOR SELECTED QUERIES, K=10

Google' result before query Expansion			**Google results for the expanded query through *Ob-SQE* system**		
Initial Query	***Average*** %		***Expanded Query***	***Average*** %	
	F.F	***P@K***		***F.F***	***P@K***
Jav / java	61.39	0	Java Programming	74.16	100
Constructor	61.43	90.8	Constructor AND Methods AND Java Programming	70.04	100
Loop	65.5	0	Loop Statements AND Statements AND Control Statements AND Java Programming	74.12	100
List	63.87	20	Lists AND Java Programming AND Collections	73.49	100
Catch	60	0	Try Catch AND Java Programming AND Exception Handling	78.52	100
Abstraction	67.94	54.7	*Abstraction* AND Java Programming AND Object Oriented Concepts	76.87	100
For	60	0	*For* AND Loop Statements AND Statements AND Java Programming AND Control Statements	75.04	100

D. System Evaluation by External Users

The *Ob-SQE* system was evaluated by two users with a good background of java programming language. Every one of them applied 45 queries with a single word. Most of these queries are processed and expanded by ontology. Yet, some of queries could not be exercised by the system, because they were not included into the ontology domain. Table II is the evaluator's feedback, which presents the number of satisfied expanded queries (therefore satisfied retrieved information) and the percentage of their acceptance of *Ob-SQE* system.

For every query, the evaluators exercised *Ob-SQE* system to generate its expanded version, and then they utilized google to test and compare the first ranked 10 results for both the original crude query and its extension.

TABLE II. EVALUATORS' FEEDBACK BASED ON P@K: UTILIZING GOOGLE SEARCH ENGINE BEFORE AND AFTER *OB-SQE* APPLICATION, K = 10

Evaluators	**Number of queries**	**Satisfied retrieved results**	**Unsatisfied results**	**Average p@10 with** *Ob-SQE* **%**	**Average p@10 with** ***Google*** **%**
1	45	37	8	**82.2**	**12.2**
2	45	41	4	**91.1**	**18.6**
Average of acceptance for two users				**86.65**	**15.4**

VII. RESULT AND DISCUSSION

Query expansion is the optimization of the crude query. In this paper, the purpose of the experiment is to verify whether the precision of the query is improved or not. Terms added to the queries have been extracted from the ontology of the Java or Python domain which is partly described in Running Example as illustrated in Fig. 4 and Fig. 5. The tested queries samples showed the effects of utilizing the ontology in improve the accuracy and increases the relevancy of the results. The results of Google alone and those after applying Ob-SQE expansion system were evaluated using the average of fitness function and the average of Precision @10. Table II, illustrates a comparison of the retrieval accuracy of queries before and after its expansion by the proposed system.

Fig. 6 illustrates the average of fitness function for the tested queries within *Qb-SQE* system and Google search engine, whereas Fig. 7 displays the average of precision of the expanded queries through the *Qb-SQE* system and that of the crude queries in Google search engine.

The evaluation of obtained results from the proposed system, a semi-automatic process was used. Since there are no Google APIs that support exact retrieval like Google search engine, and planning in the future to be full-automatic.

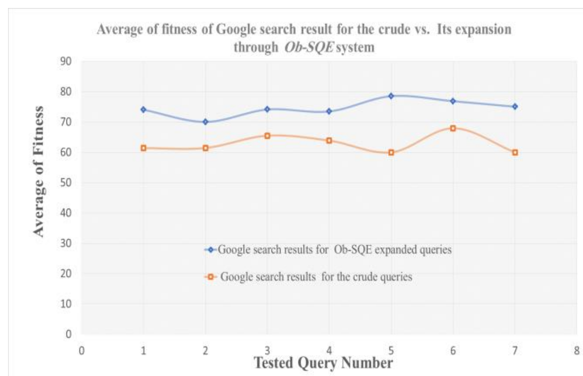

Fig. 6. Average of Fitness for the Google Searched Queries with and without *Ob-SQE* System Application.

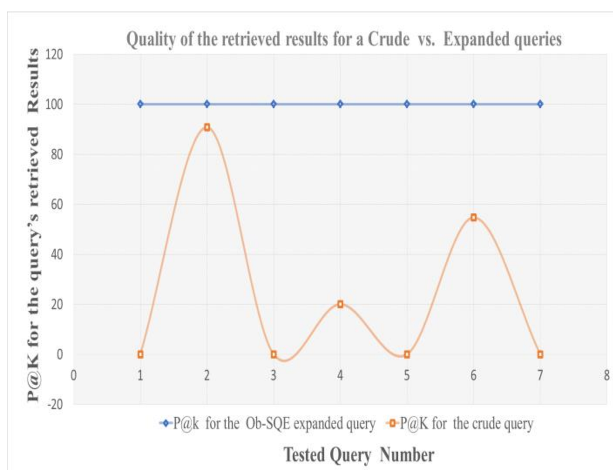

Fig. 7. Average of Precision for Google's Retrieved Results of Crude Query and its Expansion through *Ob-SQE* System.

VIII. Conclusion

The established semantic query expansion method is based on domain ontologies. It employed synonyms expansion, hypernyms expansion, and similar word expansion. The integration of similarity function into the system improved the formulated query and the quality of the searching results. The selection of computer programming language domain allowed for the manual evaluation of the system by independent and experience personals.

The developed domain ontologies improved the search process by adding context to search query. Supplying more related terms from the ontology domain cures the lack of context.

The proposed system has been tested with several number of ambiguous and misspelled queries. The semantic expansion process through the ontology domain generated extended queries, which, when executed, by the Google search engine, more relevant results were retrieved. The fitness function for the expanded queries achieved higher average (74.6) than that of the initial ones (62.30).

Average of precision @10 for the results obtained from applying the expansion (by the two external testers' personals) to a query were 82.2%, 91.1%; compared to the Google results for the original crude queries, which were 2.2%, 18.6%, respectively.

Derived ontologies are shareable and reusable. The proposed framework is applicable for any given domain, assuming the availability of the corresponding domain ontology which is developed based on super and subclasses. In future work, complete total ontology development of the domain concerned may be integrated with learning systems.

A future work may consider the end user to be more interactive with the system by creating a smart interface with him.

Also, one may consider the ontology itself to be generalized or redesigned to accommodate a higher level knowledge (like education, engineering, industry, etc.).

Since the Web is highly dynamic and forever evolving, it is essential to establish a dynamic methodology to update the knowledge ontology. Also, Auto-generated ontologies may be the solution to the time consuming and errors proning due to human errors. Furthermore, created ontologies may be integrated with learning systems to help users in the search process.

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A Cryptographic Technique for Communication among IoT Devices using Tiger192 and Whirlpool

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***Abstract*—The heterogeneous standards and operational platforms of IoT devices, introduce additional security loopholes into the network thereby increasing the attack surface for the IoT. Most of the devices used in these IoT systems are not secure by design. Such vulnerable devices pose a great threat to the IoT system. In recent times, there have been a lot of research works on improving existing mechanisms for securing IoT data at both the software and hardware levels. Although there exist cryptographic research solutions to secure data at the node level in IoT systems, there is not a lot of these security solutions that target securing both the IoT data and validating IoT nodes. The Authors propose a cryptographic solution that uses double hashing to provide improved security for IoT node data and validating nodes in IoT system. A cryptographic mechanism that is composed of the Tiger192 cryptographic hash and the whirlpool hash function is proposed in authenticating IoT data and validating devices in this paper. The use of digital ledger technology and cryptographic double hashing algorithm provided enhanced security, privacy, and integrity of data among IoT nodes. It also assured the availability of IoT data.**

***Keywords*—IoT devices; whirlpool; Tiger192; internet of things security; cryptographic communication**

I. Introduction

This paper extends an earlier conference paper submitted to the international Conference on Communications, Signal Processing and Networks / International Conference on Cyber Security and Internet-of-Things ICCSPN/ICSIoT. In our previous paper, we proposed and used a cryptographic primitive that involved the RC4 cryptographic algorithm and the whirlpool protocol in encrypting and validation of data within IoT systems [1]. The capacity of the internet of things to process large streams of data in real-time and its flexible adaptation for all environments makes it a widely adopted technology option for the collection, analysis and storage of critical data across many industrial fields as well as academia and Government installations. The spike in the adoption of the Internet of Things (IoT) across these various sectors makes it also a good target for cyber-attackers to exploit the vulnerabilities in the network. Internet-of-Things (IoT) can stream and support the creating of real time data to create new value propositions for small to large businesses, academia and governments. This unique quality of IoT system makes it one of the preferred technology of choice across all sectors of life [2]. The benefits of the innovation that IoT systems offer have been a good motivation for a lot more businesses, governments, and society to embrace in expanding access and increasing inclusiveness in the total monitoring, processing, storage, and communication of critical data in these sectors of life. The benefits that IoT systems offer have equally motivated and attracted the incidences of cyber-attacks on these systems towards the exploitation of the vulnerabilities in these connected systems.

Internet-of-Things involves several edge devices that connect to either a centralized node or distributed edge nodes to help aggregate critical data that is sensed from the immediate environments of these edge devices. The sensed data is therefore communicated through different communication protocols to the nodes. There exist several communication protocols that IoT devices adopt in transmitting data from one node to the other. These protocols include Bluetooth, WiFi, Satellite, Radio Frequency Identification (RFID), Near Field Communication (NFC). Most IoT systems use a combination of these communication protocols to connect and communicate data between each other because of the different connection requirements and capabilities from these edge devices of which sensors and actuators are the main actors in that category. These various communication protocols have their strengths as well as security vulnerabilities [3].

There are several cryptographic primitives that are used to provide privacy, integrity and confidentiality enhancements to data in IoT systems. These primitives have unique hardware as well as software platform requirements that need to be met in order to fully and effectively secure the data. Although some of these primitives have been around for decades, their ability to secure data is still relevant in recent times. The availability of modern hardware device with their heterogeneous design and operational specifications has resulted in creating incompatibilities in the dependencies for platform execution that affect the latency and throughput of these cryptographic primitives. Some classical ciphers have been broken and that makes them weak and ineffective. Such ciphers intend introduce additional vulnerabilities to any network that adopt them to secure its data. This is because, these ciphers then serve as a weak link through which cyber-attacks could be launched on the network. Man-in-the-middle attacks and its associated threats have become common place in recent IoT cyber security incidence reports. At both the system and application levels, hacking activities have resulted in data corruption, illegal data transfer and in some cases destruction of critical hardware.

There have been recent developments of several cryptographic based solutions to address IoT device security challenges that satisfy the unique operational environments of the devices to support these devices to secure communication of sensed data even with obvious operational and environmental challenges of these devices including limited computational power and storage [4].

Several security interventions continue to be proposed to secure IoT systems. Although hash functions help in protecting the integrity of data, a weak hash function is equally as dangerous as not securing the data in the first place. There is therefore the need for a strong cipher that is energy efficient and yet effective to be deployed in maintaining the needed privacy, integrity and confidentiality to assure the security of data [5]. Most ciphers secure IoT systems with particular emphasis to either the software or application layer, whiles others target the hardware or the physical layer to ensure adequate security for IoT nodes are provided to complement firewall solutions.

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The use of a cryptographic solution that involves using hashing functions and digital signature scheme to provide security to node data as well as device validation is lacking in existing reviewed works.

The paper proposes a secure cryptographic solution that ensures non-repudiation of sending activities to help with device authentication, and message validation for constrained devices in IoT systems.

The cryptographic solution consisting of Tiger192, and whirlpool hashing algorithm provide message authentication and source data validation for the communicating nodes among IoT devices. The double hashing mechanism increases resistance to hash collisions of the cryptographic solution, thus used to increase the difficulty levels in guessing the content of the messages particularly brute force attacks and dictionary attacks. The Tiger192 cryptographic hash was used because it generates a shorter digest that maps to even longer messages.

The paper is organized into five sections. Section 2 describes background notions for the paper. The review of related works relevant to the paper is done in Section 2. Section 3 describes the methodology used in the paper. Section 4 discusses the results and section 5 concludes the paper and presents expected future work.

II. Related Work

A. Whirlpool Hash Function

The whirlpool function is composed of iteration of compression function with 512-bit key space to produce a 512-bit block dedicated cipher. To encrypt data of any size, the data is padded. It is adoptable to hardware implementations on both 8-bit and 64-bit platforms. It uses a substitution box where it generates randomly its 512-bit keys to provide digital signature to data [6].

B. The Tiger 192 Hash Function

This hash function uses large translation tables and runs well on 64-bit platforms to produce a much stronger 24 bytes long output hash. It includes an internal state size of 192 bits, and block size of 512 bit. The 192-bit key size provides a stronger and better encryption. It also supports the secure exchange of keys through the internet for encryption and authentication between two communicating parties.

The Tiger and its variant hash functions consumed less energy and yet provided an enhanced security among its peers. The cost in terms of energy consumption requirements for the Tiger192 is light weight as compared to other hash functions in its category, but it produces an efficient and effective hash value that is suitable for enhancing the security of data [7]. In [8], the Tiger hash was adopted to ensure the privacy and integrity of patients' critical health data. Machine learning techniques together with a Tiger hash based cryptographic protocol were implemented to secure the communication of critical medical data of patients across several mobile medical devices and systems. Secure cloud communication scheme was based on the Tiger hash cryptographic algorithm to support secure access of cloud data. The Tiger hash was adopted at the device or the physical layer level for cloud user enrolling phases for authenticating and granting the appropriate access rights to verified users to access cloud data or services [9].

C. Internet of Things Security

Most of the devices that are used in the IoT systems were not originally built for large scale and massive data streaming purposes, yet these devices end up being used in networks that stream massive data posing a lot of security risk onto these networks. The devices then become and create a weak security link where hackers compromise such systems using such weak links as point of entry. These devices with weak security qualities and requirements have contributed to the rising number in the man-in-the-middle and it related attacks suffered by IoT networks in recent times [1][10].

In [11] the authors underscored the need for an appropriate security intervention that is efficient and scalable to help address the unique security challenges of IoT systems that cut across privacy concerns, inadequate authentication and authorizations, insecure interface designs for web, mobile and cloud as well as the absence of a security encryption at the transport layer for communication of IoT data. These devices and system vulnerabilities in IoT makes it susceptible to mand-in-the-middle attacks and other associated security incidences.

The authors identified the various implementation environments for IoT and their unique security requirements for an appropriate implementation of these security schemes to enhance the security of IoT systems. Blockchain based cryptographic mechanism was proposed to help detect and validate devices to maintain data integrity within an IoT system [12].

Every IoT security solution must include an architecture that supports cryptographic protocols and algorithms for data verification to ensure integrity and secure management of all devices and objects connected to the IoT [13].

D. Cryptographic Communication

The authors in [14] used a privacy preserving cryptographic protocol in securing location-based information as well as user critical data communicated to the cloud. The Elliptic Curve cryptographic protocol was used in exchanging and establishing secure keys between the sensor nodes in the vehicles as well as the parking areas to ensure secure and effective parking of vehicles. Zero-knowledge prove system was used to ensure the privacy of communicated information between the gateways and the cloud as vehicles searched for vacant slots to park.

In [15], an inbuilt authentication IoT platform was adopted for inventory automation. The security framework in their platform used secure and energy efficient cipher to support authentication, integrity, and confidentiality of data.

In [16], a distributed authentication encryption mechanism that is lightweight and energy efficient as well as effective at providing security for IoT was adopted and used. This encryption technique offered secure authentication and access mechanism for the IoT network. The Cipher block Chaining-Message CCM algorithm was proposed and used to encrypt data for transmission. The algorithm allowed the receiver to create a token for each sender during transmission. These tokens had expiration time to be used to help check against impersonation attacks.

A 64-bit block cipher consisting of the Feistel and a constant substitution-permutation network to encrypt data was used by the authors in [17]. The algorithm adopted fever rounds of encryption making it lightweight for IoT devices and it provided a secure framework for the IoT network to achieve their targeted results.

In [18][19][20], the privacy of sensor data was preserved using blockchain and cryptographic schemes to guide the design approach of an IoT system. In their design approach, a blockchain concept was adopted in preserving the data through the generation, procession, and exchange of data across storage location. The use of blockchain was adopted in ensuring a tamperproof distributed and decentralized storage of sensor data for edge devices as hosting environment in IoT.

In [21][22][23], key pairs are used for the generation of the HMAC (Hash Message Authentication Code). HMAC assured message authentication as well as node validation for the sender node. The Tiger 192 hashing function served as the authentication function in providing integrity for IoT data from the source nodes to the receiver node.

III. Methodology

In Fig. 1, several edge devices are connected to a centralized node to coordinate device enrolment, authentication and authorization towards the communication of sensed data from the edge devices. The various edge devices are identified using their unique IP addresses. The centralized node helps with registering and authenticating all the edge nodes. These connected edge devices collect critical data from their environment and transmit it to the centralized node. The centralized node has enhanced computing power to process the transmitted data by intelligently measuring, analyzing and interpreting the sensed data from the edge devices.

The node serves as a hub for group enrollment of all sensors by adopting a common authentication mechanism to share a configuration for these sensors $(DN_1 - DN_\infty)$. The node coordinates and manages symmetric key certificate for encryption of data. The sensor and the node employed the same pre-shared encryption keys for secured communication between them.

At the application layer level on these nodes is implemented a blockchain-based digital ledger that records the unique attributes and data across all the connected nodes. All the edge nodes are cryptographically linked to store the updated state of all the validated data, distributed across the nodes.

Edge device enrolment onto the dedicated centralized node happens in two steps. The device gets registered on the centralized node using a key exchange protocol used to provide the needed credentials. The registration and certificate authorities are implemented on the centralized node to help coordinate device enrolment as well as authentication of edge devices. The enrollment and authentication occur through device provisioning. The just-in-time provisioning approach is adopted.

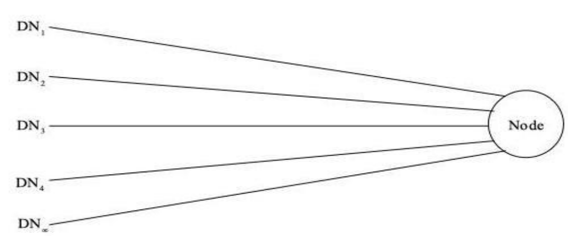

Fig. 1. Connected Edge Devices to a Node in an IoT System.

TABLE I. DIGITAL LEDGER IMPLEMENTATION TABLE AT THE NODE LEVEL

ID	SN	Data	Timestamp	Whirlpool	Tiger192
1	SN_1	D_1			
2					
3					
4					
5					
…	…	…	…	…	…
L	SN_L	D_L			

As shown in Table I, the distributed ledger to be implemented on the centralized nodes with its composition is displayed. It contains the various fields and components that constitute the digital ledger.

ID – Denotes the unique identifier to each connecting edge device or node in the IoT. It usually represents the component or part identification number of the sensor. For easy identification on a connected system, every object or connected device is assigned a unique sequence of hexadecimal values or alphanumeric value. The $ID_1 - ID_L$ denote the identifier of the first connected device to the last identifier respectively of the connected devices to the IoT. These identification labels are uniquely generated strings to represent each connected device[24].

SN – Represents the sensor or device name. IoT devices are named using various conventions and standardization criterion [25][26].

Data – This describes the message or information to be communicated. It is a plaintext data collected by an edge device or sensor from its immediate environment. It could be a temperature, hygrometer, electric voltage or other physical measurement value.

Timestamp – The timestamp component in the hash table denotes the specific date and time that the data or message arrived at the device. The timestamp consists of the date and time components that records the actual date and time the message or data arrived at the at the centralized node[27][28]. The date component comprises DD/MM/YYYY whereas the time component includes the HH:MIN:SEC. DD, MM, YYYY, HH, MIN, SEC represents Day, Month, Year, Hour, Minute, Seconds respectively.

Whirlpool – The message digest of the data to be communicated is produced using the whirlpool cryptographic hash function. The message digest is then stored in the whirlpool field, for each data.

Tiger192 – The digital fingerprint value or digital signature of the encrypted message is created using the Tiger192 cryptographic hash for each message. The digital fingerprint for message digest is stored in the Tiger192 field.

The whirlpool hash is computed using:

Hash (Data, Device Name, Timestamp, Previous Hash)

The plaintext message to be hashed is segmented into blocks.

$m_1, m_2, m_3, \dots, m_t$

H_o=initial value

$H_i = E(H_{i-1}, m_i) \oplus H_{i-1} \oplus m_i$ intermediate hash value

H_t=Hash code value

m_i represents the current message block for the plaintext

E represents the block-cipher-based hash function for Whirlpool

H_i represents the intermediate hash value

H_{i-1} represents the hash value for the previous iteration.

H_t denotes the hash code value

The output hash value (H_i) is computed using the bitwise XOR operation on the current message block, the intermediate hash value from the previous iteration and the output of block-cipher-based hash function of Whirlpool (W).

The output hash code for the whirlpool cryptographic algorithm is a 512-bit size message digest [29].

The Tiger hashing algorithm is used to implement a Hash Message Authentication Code (HMAC).

Three main components constituted the Tiger 192 hashing algorithm. Key generation algorithm, Signing Algorithm, Verifying Algorithm [30].

The key generation phase:

The key generator ensures the generation of the private and public keys for the two nodes.

The private key of the sender node is used to generate the digital signature for the message using the resultant hash code value of the whirlpool hash and the sender private key as the input strings.

$Sig_1 = H(H_t, SP_rK)$

Where:

Sig_1 -- represents the digital signature generated at the message originating node.

H -- is the Tiger192 Hashing Algorithm.

H_t -- denotes the hash value code, a resultant message digest.

SP_rK -- represents the sender's private key.

Sig_1 is the digital signature or the Hash Message Authentication Code (HMAC) for the message digest from the node originating the data to be communicated. The message to be sent to the receiver is a composition of the sig_1 and H_t.

At the receiver node,

The Private key of the receiver node (RP_rK) is used to decrypt the signature.

$Sig_2 = H(H_t, RP_rK)$

Where:

Sig_2 -- represents the digital signature generated at the receiver node.

H -- is the Tiger192 Hashing Algorithm.

H_t -- denotes the hash value code, a resultant message digest.

RP_rK -- represents the receiver's private key.

The resultant hash from the decryption is compared with the hash of the message.

A. Signature Verification Process

The signature verification process is performed using the private key of the receiver node, the hash value (H_t) and the signing algorithm in Tiger192. It is carried out at the base station serving at the sink nodes (T_1 and T_2) using the sig_1 and sig_2 values.

1) Obtain hash code value H(M) and sig_1 (HMAC) from source node.

2) Apply private key of receiver node on the hash code to obtain sig_2 (HMAC).

3) Compare the sig_1 and sig_2. HMAC and HMAC values for source and receiver nodes respectively.

4) Check for same. strings in the sig1 and sig2. If fails, reject signature and message.

5) Otherwise, use the reverse whirlpool on the hash to regenerate the message.

IV. Result

As shown in Fig. 2, nodes T_1 and T_2 are IoT nodes that have adequate computational and storage capacity to support the provision of connectivity for edge devices mainly sensors.

Both nodes adopted a centralized approach towards device enrollment and authentication for the IoT device provisioning. Registration and Certificate authorization mechanisms were implemented on these nodes (T_1 and T_2) to help them manage, coordinate and control the smooth enrollment and management of all the edge devices that were connected to them. The node serves as a hub for group enrollment of all sensors by adopting a common authentication mechanism to share a configuration for these sensors ($DN_1 - DN_\infty$). The node coordinates and manages symmetric key certificate for encryption of data. The sensor and the node employ the same pre-shared encryption keys for secured communication between them.

Sensor data from the edge devices are hashed using the whirlpool cryptographic hash function. The encrypted data is stored on the centralized node on each of the two nodes (T_1 and T_2). The stored encrypted data is stored in a blockchain-based digital ledger. The distributed ledger technology implemented on the two connected nodes ensured the replication of storage of encrypted data across the two connected nodes. The use of the digital ledger and the subsequent duplication across the connected nodes eliminate the occurrences of single point of failure that would result in data loss in the IoT.

Table II represents data storage of hashes in the digital ledger and the duplication of storage on the blockchain digital ledger across the connected sink nodes.

The system in Fig. 2 demonstrated a digital ledger containing encrypted data which is based on the blockchain digital signature concepts. The hash table with their content is shared across the two connected nodes; thus, a source node and a destination node.

TABLE II. DISPLAYED RESULT

ID	SN	Data	Timestamp	Whirlpool	Tiger192
1	2	5465 41	06/05/2019 01:04	837b2f65671b3f0ce 5ace81f3fa251ea7a2 c5c5fcba211c234f2a 23f83654ea406ecd2 8f90d6e7569b1ffc94 732ca6d977ffe3cda0 ec8b44d1619cf8bae 22bcf	3720495933 94e34bbe0c deb5aafd04 c1e8d1c893 77839723
2	3	6695 66	06/05/2019 07:56	f045dfeab2c2ba445 dbf95ebfa9dbbcbdc 204f40094b88221ed 8873657e3fbe5986a fa6eb522873614947 452c1c44587193ba5 d2d7ae858bb39102f 23e7195da	0245b4eb07 777000a4ce f45323f96c 663566e67d 7515b553
3	4	6595 26	06/05/2019 04:38	367d7dbea6ed284bb 82802c6ffca369212 25f7e39ebfdbd3516 d94ab828b4cfed19a 08c5840666982c5a2 1a26cdb98aa333693 240da63f58eb6795a 6d9e40508	aa2dc71498 3dad807cab b5432a164d e4541f3a11f 044fb42
4	1	4549 86	06/05/2019 11:27	636a0c83e50f159b0 b5bfebdce07c1f8a67 b9320508bbedcbfff3 b5963c9c35f7f3745 109f0cc9d3b91b500 99173556d56dbb06f 5771f8c6f6ed109b2 28d32fd	cb3ebced2e d66321a21b e77063bd4f 7ea355188a 5eeaf14f
5	2	3654 95	06/05/2019 06:05	121d28efb1649a007 a5307c314a88c5f48 c95405e59c6252a1a df18a8a3cda32cf2d3 2c76be51dd9d7cd19 7091c58134706983 140ce9bb8a9f24a08 66ebb480d	1be15d54f3 0f24d7c7f6a 1cd757e39c 6e40f5e530 80f098b

Fig. 2. Two Nodes T1 and T2.

The hash function ensured that the data and the unique components of the hash function were not tampered with, since any alteration of any of the hashing components will result in a different hash. The distributed storage of the digital ledger between the source and the destination nodes is compared for detection of tampering of IoT messages. The hash tables of both nodes must produce same values. Any modification of the message will produce a different output for the hash table. The use of the cryptographic algorithm and the hash function guaranteed the security, privacy, confidentiality, and availability of the IoT data. The Tiger192 cryptographic hash generated a digital signature for each content of the message. The private key of the sending device is used in generating the digital signature of the content of the message. The digital signature produces a shorter message digest that maps onto the content of messages. The Tiger 192 generated a digital signature for each cryptographic encryption produced. The digital signature assists in authentication of the content of messages. The Tiger 192 signed messages provided non-repudiation in validating the authenticity of the sending node. The public key of the sending node can be publicly verified even by unintended recipients within the network. The digital signature is based on the content of the message being signed. Both the ciphertext and digital signature are communicated between the communicating nodes.

Message integrity and authenticity is verified using the HMAC (keyed-hash message authentication code). The shared secret between the communicating nodes (T_1 and T_2) provided data origin authentication as well as message integrity.

V. Conclusion and Future Work

This paper adopted a hybrid cryptographic scheme that included the Tiger192 cryptographic algorithm and the whirlpool hash function to support secure communication of IoT devices. Data to be communicated was hashed using the whirlpool cryptographic hashing function. The Tiger 192 hashing function was used to generate a digital signature, a shorter digest that tagged and mapped onto the content of messages. The whirlpool hash served as the building block for encrypted message and the message authentication code or digital signature is then communicated between the source node and the destination node. The security and strength of a cryptosystem is based on the length of the key size. The 192-bits key size assured a stronger and produced a shorter mapped digest for all messages particularly for longer messages. The use of the Tiger cryptographic algorithm provided a complementary security layer to assure message authentication using the HMAC. Tampering of data incidences are detected and addressed since the digital ledger replicates storage of encrypted data across all connected nodes. The storage of data across the connected sink nodes assured data availability since single point of failure incidences were eliminated with the digital ledger technology. Node authentication assuring the identity of the source of the data is enforced using the key public key of the sender node to enforce non-repudiation. It also protected the integrity of data by validating the genuineness of the data communicated using integrity authentication through the comparing of the digital signature tags on the sender and receiver nodes. The double hashing used increased the resistance to hash collisions of the cryptographic solution, thus used to increase the difficulty levels in guessing the content of the messages particularly brute force attacks and dictionary attacks. The double hashing cryptographic mechanism consisting of the Tiger192 cryptographic hashing scheme, and the whirlpool hash function increased the security, privacy, and integrity of IoT data. The use of the digital ledger technology assured availability of data.

The use of the digital signature assisted in authenticating IoT data whereas the validating devices in this paper. The use of digital ledger technology and cryptographic scheme of double hashing algorithm provided enhanced security, privacy, and integrity of data among IoT nodes. It also assured the availability of IoT data.

The key pairs used for the generation of the HMAC assured message authentication as well as node validation for the sender node. The public key of the sender node helped in enforcing non-repudiation of the origin of data as well as device verification. The authentication function provided by the Tiger 192 provided integrity for data from the source nodes to the receiver node. Since the public key of the sending device is available within the network, the source of the message can be validated enforcing non-repudiation.

An implementation of this combined cryptographic algorithm on an IoT platform would be explored for future works.

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User-centred Design and Evaluation of Web and Mobile based Travelling Applications

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***Abstract*—Travelling has been known as one of the top-rated activities people do during their leisure time. In this digital time, people usually research before visiting a new place to avoid unpleasant events and to have a well-planned trip. Due to the complexity of search engine browsers, people have been switching to designated travelling applications. Travelling applications should be designed by taking into consideration user's needs and requirements; and usability. This research aims to design a travelling application based on a user-centred design approach and compare its performance on different platforms. Two prototypes of travelling applications were designed and evaluated; web-based and mobile-based. Then, System Usability Scale (SUS) questionnaire was used to evaluate the usability of the two prototypes. Pearson correlation coefficient test and t-test were used to analyses the data collected from the questionnaire. The results showed no statistically significant difference in SUS scores for both prototypes, which indicates that the participants do not prefer any of the prototypes more than another one.**

Keywords*—Usability; travelling application; SUS questionnaire: low-fidelity prototype; user-centred design (UCD)

I. Introduction

Recent development of information and communication technologies has played a central role in the growth and improvement of the travel and tourism industry [1, 2, 3]. Numerous travel and tourism practitioners attempt to understand the effects of IT applications in managing and distributing travel products and services [4]. Interesting information about travel destinations and other required services (such as accommodations, restaurants) is commonly searched via the Internet by tourists to plan a trip [2]. However, the results obtained by the search engines may be overwhelming, complex and time consuming for tourists. A few problems have been determined using search engines, such as poor queries, language barriers, and inefficiency due to the abundance of resources available on the web of the new places. Many people do not know how to express what they want in the real world and are even worse when using a search engine [5].

Moreover, search engines consider language factors when ranking results. Results in languages different from the language the user uses give a lower ranking [6]. The results from the search engine also sometimes are not related to the one that users tend to search. Hence, people have been switching to designated travelling applications to ease themselves in finding related information efficiently. Travel applications offer various functionalities for tourists, such as hotel booking, car renting, and flight booking [7]. These applications are considered the most downloaded applications around the globe [8].

In the competitive travel and tourism industry, user-centered design and usability are key factors for successful travel websites [7, 9-14]. Usability is a quality attribute that evaluates how easy user interfaces are to use, and it is a necessary condition for survival [15, 16]. If a travel application is difficult to use, people will leave to other competitor applications [7].

Research investigating user behavior to a travel application found that travelers have a positive attitude towards the application and produce positive usage intention, leading to the future formulation of new travel application policies and strategies [17]. In the study of travel application attributes and features, Fang et al. [18] proposed a research framework based on the Stimulus-Organism-Responses model to explore how the application attributes and characteristics could stimulate travel application engagement. The results reveal that user interface attractiveness, privacy, compatibility and ease of use are important drivers of users' behavioral engagement of travel applications.

Although various tour travel applications were developed to guide tourist activities [19-23], there is a lack of research that designs a travel application considering users' requirements and needs and usability. This gap motivated this research which concerned designing a usable travel application based on users' requirements and needs. Considering user's requirements and needs is important when designing and developing applications to ensure that the application will be accepted [24, 25]. Other advantages of designing usable travel applications include: increasing the success and profits of the travel applications; contributing to the growth of the economy by increasing revenues generated from tourism [11]; and improving users' experience and interaction.

This research aims to design and evaluate a web-based and mobile travel application based on users' needs and requirements. The specific objectives of the study are:

1) To collect users' requirements and needs regarding travel applications;

2) Based on Objective 1, to analyses the results and to design two prototypes: web-based and mobile;

3) To use the System Usability Scale (SUS) questionnaire to evaluate the usability of the two designed prototypes.

The results of this research would offer advice to travel application managers and designers on how to design usable travel applications by considering usability issues and users' requirements and needs which will be identified in this research.

II. Related Work

A. Usability of Travel Websites

Various studies were found in the literature concerning the usability of travel websites. These studies can be divided into two categories: studies that employed various methods to evaluate travel websites' usability and other studies that suggested heuristics or guidelines to design or evaluate the usability of travel websites. The first category shed light on common usability problems on travel websites that can be considered and when designing travel websites. The second category, which suggested heuristics to evaluate the usability of travel websites, can also help develop travel websites by considering the identified criteria in the design and development of the new travel websites.

For example, Carstens & Patterson [26] employed a user testing method to evaluate the usability of three common travel websites: Expedia.com, Orbitz.com, and Travelocity.com. The usability problems identified on the tested travel websites include: not easy to interact with the websites; inappropriate use of background and text colours; cluttered pages; compatibility; unavailability of in-depth search capabilities. Also, Ismail et al. [23] conducted a user testing method to evaluate the usability of four tourism websites in Malaysia and identified usability problems on these websites. The usability problems related to inconvenient data; outdated content; the user interface is displayed only in the English language; crowded content; require information from other websites; and slow loading of pages.

Furthermore, Bainbridge [7] conducted user testing methods to evaluate the usability of 87 hotel booking websites, including 16 travel agencies, 43 hotel booking agencies and 28 hotel chains. Examples of the usability problems identified specifically on the travel agencies include lack of displaying how the rate is calculated; long booking process; not handling multiple occupancies and multiple rate reservations, and not taking children's reservations. Based on the results obtained from the analysis of the usability problems, Bainbridge [7] suggested 25 key design characteristics (usability guidelines), which addressed the identified usability problems. The categories of the booking process design guidelines are the overall structure of the booking process, multi-room check-out, children, and displaying rate values.

Alternatively, Limayem et al. [27] employed a heuristic evaluation method to evaluate eighty travel agency websites in Hong Kong. The results showed that the interfaces of these websites were poorly designed and did not adhere to the well-known design guidelines in terms of ease of navigation and consistency. The usability problems which were found on the travel websites include: lack of providing special features (such as last minutes discounts); inappropriate content (such as content was not updated, presenting confusing, unclear and vague information); the content was displayed only in the Chinese Language; lack of proving value-added services; lack of providing clear privacy statements.

However, Karanasios et al. [28] suggested a specific framework for designing or evaluating mobile tourism applications, consisting of four dimensions, ten features, and ten corresponding criteria. The dimensions are related to Service delivery, customization, and initiation and application type. Hashim and Isse [24] also proposed thirty-five usability evaluation metrics for tourism mobile applications, which can be used to design usable mobile applications for tourists. The metrics related to five usability dimensions, namely: Effectiveness, efficiency, learnability, satisfaction and error. The suggested metrics were verified and agreed by five experts to be accurate and applicable for tourism mobile applications usability evaluation.

B. Travel Application for Guiding Tourist Activities

Mobile travel applications were classified into four main categories [2]:

- Online Booking: these applications allow users to make online reservations for various services such as car rental, hotel, and airplane tickets.
- Information Resource: these applications provide the user with useful information during the trip, such as tourist destinations, flight tracking, the airport and accessible services.
- Location-Based Services: these applications provide the user context-based information based on their location, such as map and navigation services, police phones, and hospitals.
- Trip Journals: these applications allow the user to accumulate and analyses information related to the trip, such as: calculate the money spent for the journey.
- Setten et al. [19] described a context-aware mobile tourist application COMPASS, which provides context-aware recommendations based on both the user's interests and his current context. COMPASS is built upon the WASP platform, which provides generic supporting services with semantic web technology [2].
- Smirnov et al. [2] proposed a "Tourist assistant – TAIS" mobile travel application related to Information Resources and Location-Based Services categories and recommended tourist attractions. TAIS applications generate recommendations for the tourist about interesting attractions around. TAIS response time was tested regarding the response time, and it was found that it will not take more than few seconds for every operation.
- Anacleto et al. [20] presented PSiS (Personalized Sightseeing Planning System), a mobile tour planning support system. It is designed to support tourists during

their vacations by providing recommendations to the user based on their preferences. PSiS also suggest a visit planning that can be dynamically adapted based on the current user and sight context. The user can use PSiS via the special web application or the special mobile application for Android-based smartphones.

- Kramer et al. [21] described the development and evaluation of Dynamic Tour Guide (DTG), a mobile tourist guide. DTG supports the user based on the actual context, defined by personal interests, location and schedule. It enables a personalized, automatic and guided tour just like expert guidance. It computes an individual tour in real-time by considering available context information like personal interests and location-based services. It captures the user's interest profile and use it to rank and select concrete attractions in a destination to compute a personalized tour.
- Cheverst et al. [22] presented the development of GUIDE, a context-aware electronic tourist guide designed to guide tourists in the city of Lancaster, the UK. GUIDE suggested a tailored tour to the user based on their profile, contextual information and physical location. The user can change the tour. GUIDE also provides various booking facilities to the user.
- Ismail et al. [23] described the process of developing the iTourism Travel Buddy Mobile Application, which is a travel mobile application that was developed to support tourists in finding interesting places and related services in Malaysia. iTourism provides users with sufficient information regarding places to visit supported by actual images. It also offers tourist a secured journey since it can reconfirm the information and the places while matching it with the data from GPS.

III. Research Method

As shown in Fig. 1, this study is conducted in three phases: user requirement study and analysis, designing and developing a prototype, and usability testing and evaluation.

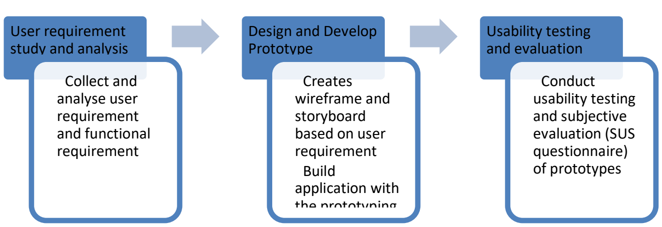

Fig. 1. Three main Phases of the Methodology.

A. User Requirement Study and Analysis

This phase mainly collected the users' opinions, thoughts, ideas, and feelings about planning a trip, and the feature or platform of the needs to plan a trip effectively. The user requirement study via questionnaire-based was conducted as the data gathering method. The questions are based on: earlier research which developed travel applications for guiding tourist activities, presented in Section 2.2, and usability guidelines which should be considered while developing travel applications, presented in Section 2.1. The questionnaire consisted of 22 questions, where these questions collected participants' personal information such as an e-mail address and their nationality. User requirement data were collected to study the participants' behavior, such as their thoughts, travel style, experience, a problem user's face while planning a trip, and their expectations of the new system in terms of feature, convenience, flexibility, and functionality. The survey questions were formed into two types: the user requirement used a qualitative method, and the functional requirement used a quantitative approach. The answered questions were based on their own opinions and experiences, followed by their expectations of the new coming system built with the proposed solutions. The questionnaires were given to 50 potential participants. The Results and Discussions Section presents the analysis of the user requirement.

B. Design and Develop Prototype

The storyboard was created to illustrate functional application requirements. Storyboards help establish a hierarchy for elements within a page, clearly define the grid and structure of the site, and help communicate to the team what the final piece should look like [29]. Next, a wireframe was created from the storyboard and then developed the prototypes using a prototyping tool (e.g., Figma).

C. Usability Testing and Evaluation

After the prototypes were designed, usability testing was conducted to evaluate the prototypes' usability and identify usability problems [30, 31]. User performance analysis with usability testing was conducted and collected information of subjective satisfaction using the SUS questionnaire. Fig. 2 shows the methodology of usability testing and evaluation that was used.

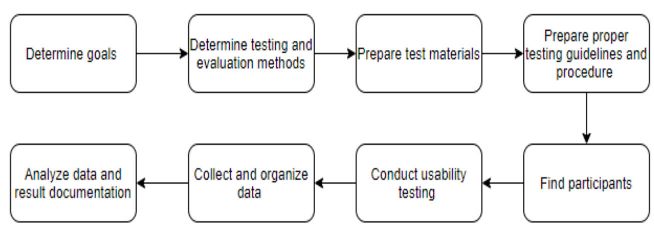

Fig. 2. The Methodology of Usability Testing and Evaluation.

1) Determine goals and testing methods: The primary purpose of this phase is to conduct a usability evaluation of the two prototypes to identify which prototype is preferred by the user. User performance analysis was chosen to collect subjective satisfaction using the System Usability Scale (SUS) questionnaire [32, 33].

2) Preparing test material: The test material was divided into three parts:

a) Prototype: In the previous phase, two interactive prototypes were designed using the Figma prototyping tool. This type of prototype allows to test design concepts and get feedback on the flow or functionality of a design [34]. One of the prototypes is a web-based prototype, while the other is a mobile phone prototype. In this study, prototypes are called modules. The web-based prototype is module 1, and the mobile app prototype is module 2.

b) Task: To test the user performance of both prototype versions, the participant was allowed to use and interact with the prototypes. It is crucial to ensure that the tasks are appropriately made based on user requirements and functional requirements gathered from the first phase.

c) Post-test questionnaire: This questionnaire is given after the participants have completed all given tasks scenario for each prototype. The primary purpose of the post-test questionnaire is to collect preference information from the participants to identify the application strengths and weaknesses. The System Usability Scale (SUS) questionnaire has used 10 Likert-scale questions and produced a score from 0–100 [32, 33].

3) Participants: Ten (10) participants were selected based on a purposive sampling method [35-37]. Moreover, it allows researchers to extract helpful information from the collected data, which is extremely time and cost-effective.

4) Conducting the test: Participants must follow the given procedure and guidelines and need to record their screen while completing the tasks. The video recording(s) was shared after completing the tasks for analyzing and evaluating. This method allows us to gather qualitative data of the test, such as capturing what participants did to complete the tasks [32]. The post-test questionnaire given to the participants was used to collect the subjective satisfaction from participants. The data collected from this questionnaire is the metric used to determine the usability of the prototypes.

5) Data analysis: From the recorded video, participants' task time to complete the test was calculated for each prototype. The formula is as follows:

$$Task\ Time\ =\ End\ Time - Start\ Time \tag{1}$$

From the task time of both modules, the Pearson R coefficient test was conducted to determine the correlation between modules 1 and 2. Next, the SUS questionnaire scores were calculated, and this data's mean and standard deviation was found. Finally, t-test analyses were performed.

IV. Results and Discussion

A. User Requirement and Analysis

Thirty-six (36) participants responded and shared their own opinions and comments on the questions about travelling activities used in the study. Most participants were primarily dependent on the internet search engine in their travel planning. Most participants think search engine browsers still provide them with the relevant answer, but most of them also agreed that it is difficult to find eateries and hot spots of a new place. We discovered that most of the participants are hesitant to hire a freelance tour guide. We also found that in this new era and new lifestyle, people nowadays are willing to accept the concept of "online", which greatly impacts humans, especially in terms of business and travelling. It is an expected result because this feature is new and has never been created by any systems yet. The output from the user requirement study is illustrated with an empathy map. Fig. 3 shows the empathy map of traveler opinions of the planning process before beginning a trip.

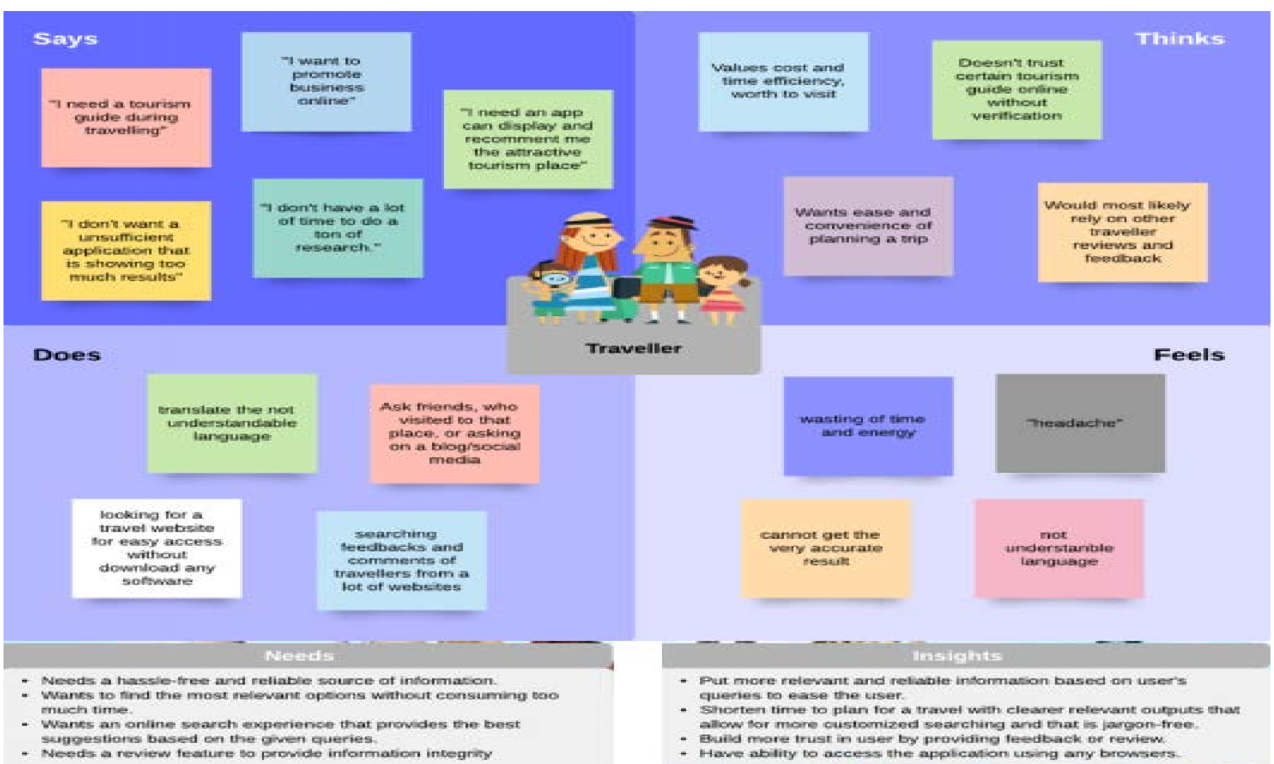

Fig. 3. Empathy Map of Traveler Opinions of the Planning Process before beginning a Trip.

B. Prototype Development

Fig. 4 shows some parts of the mobile application prototype, and Fig. 5 shows some parts of the web-based desktop prototype.

A comparison between the designed prototypes with the earlier developed travelling systems, presented in section 2.2, showed similarities between them in providing recommendations to users regarding attractions and tour guides [2, 21-23]. However, this research uniquely took into considerations users' requirements and needs while designing the prototypes. Also, this research designed two prototypes (web-based and mobile) to increase the flexibility of the designed prototypes.

Overall, the UCD approach is chosen because it focuses on the end-users and has been proven to enhance task efficiency and usability of many websites and mobile applications [40, 41]. Travel-related applications should provide a platform to ease the travelling experience for the user. Therefore it's important to adopt a user-centred approach at the earliest stage of travel-related websites and mobile application design and development processes. These could give the end-user the ability to establish and validate important features of travel-related applications.

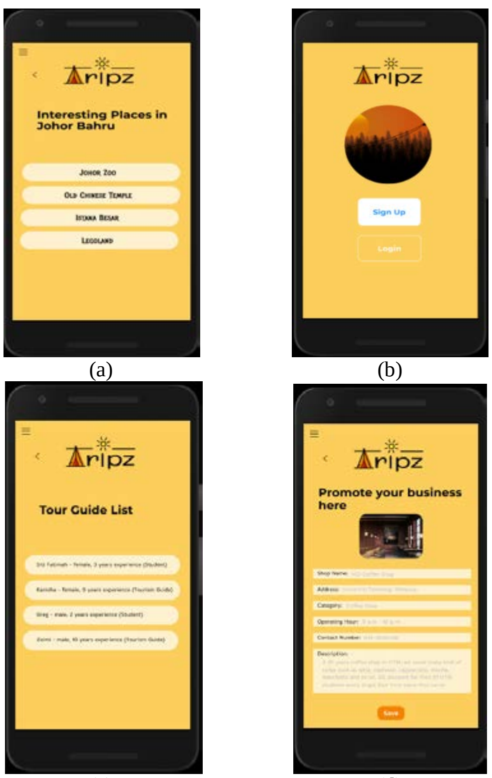

Fig. 4. Preview of Desktop Prototype: Home Page (a), List of Interesting Places in Johor Bahru (b), Tour Guide List (C) and Vendor Promote Business form Page (d).

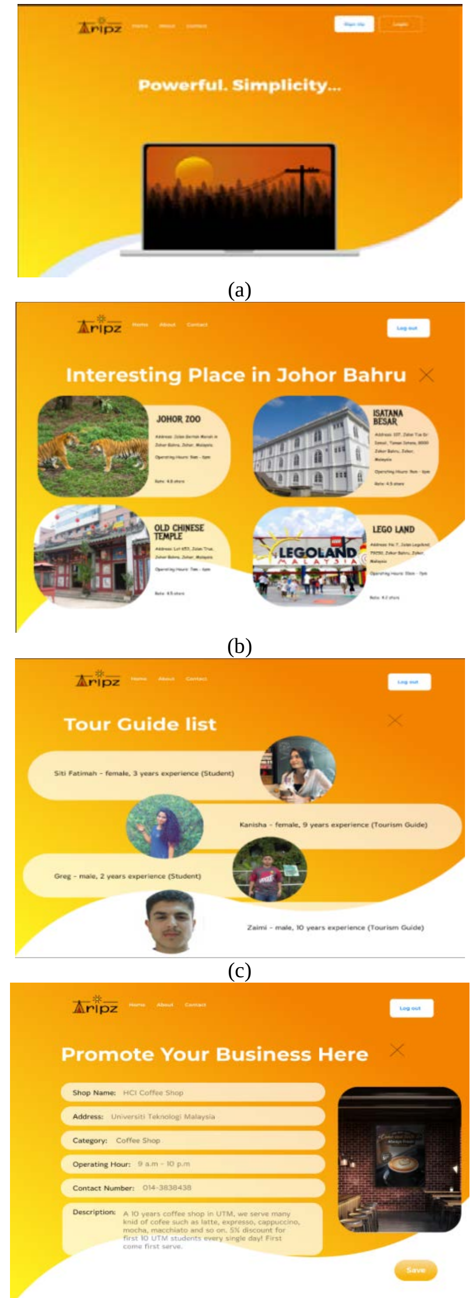

Fig. 5. Preview of Mobile Prototype: Home Page (a), List of Interesting Places in Johor Bahru (b), Tour Guide List (c) and Vendor Promote Business form Page (d).

C. Prototype Development

Fig. 6 shows the task times by each participant for both prototype modules. Meanwhile, Fig. 7 shows the correlation between the task time of Module 1 and Module 2 participant for both prototype modules. Meanwhile, Fig. 7 shows the correlation between the task time of Module 1 and Module 2.

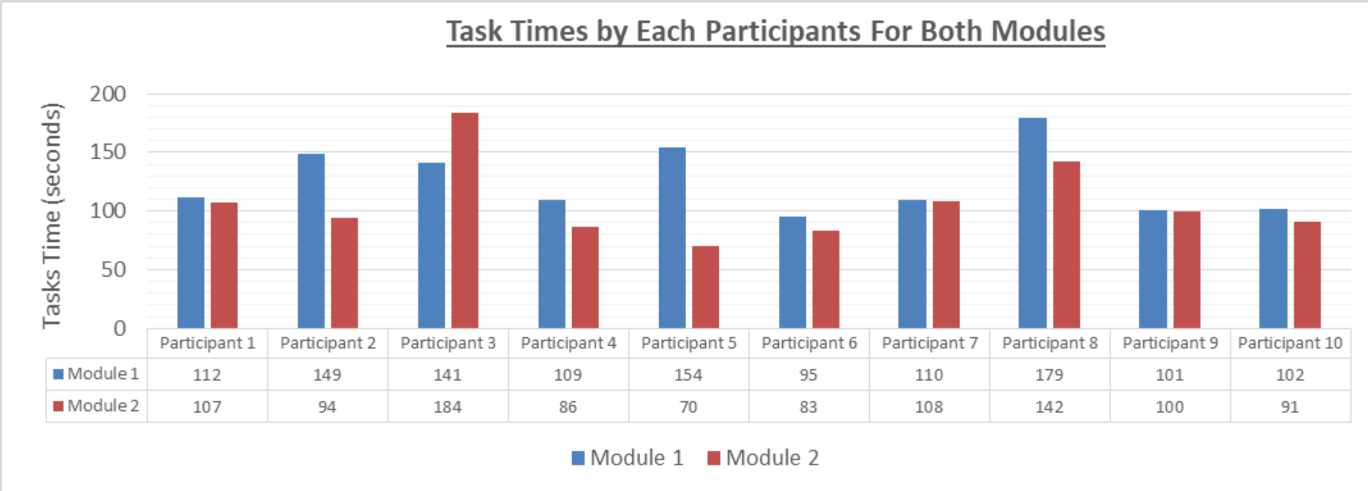

Fig. 6. Task Times by Each Participants for Both Modules.

Fig. 6 shows that participant 3 took the longest time to complete the tasks. To exert a conclusion from this data, the Pearson r correlation test was conducted to determine whether the task times of module 1 and module 2 are correlated to each other. The results of the test are shown in Table I. Since the result is 0.389 ($-1 < 0.389 < 1$), it means that they are correlated to each other. Additionally, a scatter graph was used to determine whether the correlation between the modules is strong or weak. The graph showed a weak positive correlation. In conclusion, task time for modules 1 and 2 has a weak positive correlation from this correlation result. This indicates that these modules are correlated, but if one variable experiences increments or decrements, the other variable is unlikely to be affected.

In this study, the SUS scores were used as our subjective satisfaction measurement. Table II shows the SUS final scores of each participant for both the prototypes and the mean, standard deviation, and standard error of each module.

A clustered column chart was used to represent the mean result and compare the results graphically, as shown in Fig. 8. As can be seen from Table II, participants 6 and 7 gave low scores. From the recordings, notably, these participants had difficulty dealing with the prototype's button. Comments also were provided from the survey such as "should create a clearer "x" button" and "The flow of the website is not smooth. Also, there is a button that cannot be clicked. It is straightforward, but the button hasn't been fully utilized yet. These two participants' assumptions gave low SUS scores due to the technical issue experienced by the prototypes' buttons. Module 1 (web-based prototype version) has a higher mean than module 2 (mobile application prototype version).

TABLE I. PEARSON R CORRELATION TEST RESULT

	Module 1	*Module 2*
Module 1	1	
Module 2	0.389256	1

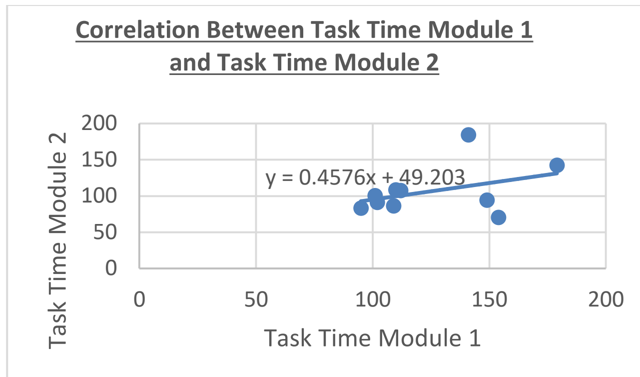

Fig. 7. Correlation between Task Time Module 1 and Task Time Module 2.

TABLE II. THE SUS FINAL SCORES OF EACH PARTICIPANT FOR BOTH PROTOTYPES

	SUS Final Score	
	Module 1	**Module 2**
Participant 1	90	75
Participant 2	82.5	92.5
Participant 3	92.5	82.5
Participant 4	80	80
Participant 5	90	92.5
Participant 6	52.5	55
Participant 7	57.5	57.5
Participant 8	97.5	95
Participant 9	77.5	77.5
Participant 10	87.5	90
Mean	80.75	79.75
N	10	10
Std dev	14.8628	14.16422
Standard error (SE)	4.70003	4.479118

Earlier research also identified these problems, which evaluated the usability of travel websites, as presented in section 2.1. Specifically, the two issues were identified earlier:

- Not being easy to interact with the website [26, 27];
- Presenting inconvenient, confusing, unclear and vague information [23, 27].

However, while considering the usability problems identified in earlier studies and the suggested usability guidelines recommended by earlier research, this research designed usable prototypes. Only a few issues were identified by the users.

A t-test was used to determine if there is a significant difference between the means of module 1 and module 2 [38, 39]. The t-test value (t = 0.154) and the p-value (p = 0.879), as shown in Table III show no statistically significant difference in SUS scores for prototype 1 and SUS scores for prototype 2. The SUS scores show that the participants do not prefer any of the prototypes more than another one.

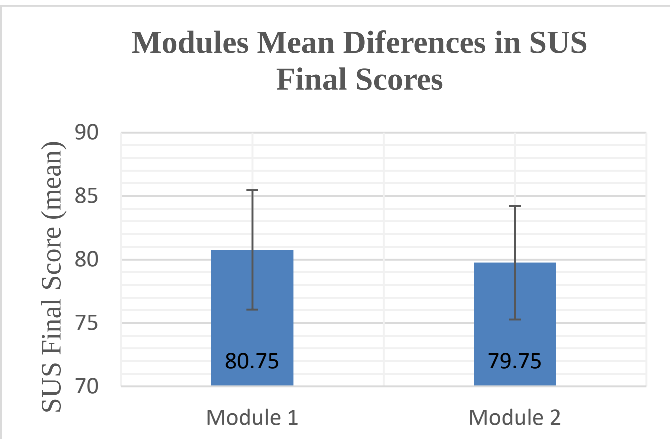

Fig. 8. Clustered Column Chart of Modules Differences in SUS Score.

TABLE III. T-TEST RESULT

t-Test: Two-Sample Assuming Unequal Variances		
	Module 1	*Module 2*
Mean	80.75	79.75
Variance	220.9028	200.625
Observations	10	10
Hypothesized Mean Difference	0	
df	18	
t Stat	0.154023	
P(T<=t) one-tail	0.439652	
t Critical one-tail	1.734064	
P(T<=t) two-tail	0.879305	
t Critical two-tail	2.100922	

V. CONCLUSION

Nowadays, travel applications are the most downloaded applications around the globe. Therefore, it is crucial to have a usable travel application to help the travelers manage their journey and help the travel and tour agency manage their services. This paper aimed to propose an application system design that is easy to use, reliable, and provides the users with the necessary information. Firstly, to gather information on whether users would accept the system, a survey was designed regarding the features and functions proposed for the application. After that, a storyboard was created, a wireframe was designed, and finally, two low-fidelity prototypes were developed using Figma: desktop web-based prototype and mobile prototype. Then, usability testing was employed using the System Usability Scale (SUS) questionnaire. The results showed that users have no preference towards any of the prototypes. The next step is to develop the designed prototypes taking into consideration the usability problems which were identified.

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Experimental Study of Hybrid Genetic Algorithms for the Maximum Scatter Travelling Salesman Problem

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***Abstract*—We consider the maximum scatter travelling salesman problem (MSTSP), a travelling salesman problem (TSP) variant. The problem aims to maximize the shortest edge in the tour that travels each city only once in the given network. It is a very complicated NP-hard problem, and hence, exact solutions are obtainable for small sizes only. For large sizes, heuristic algorithms must be applied, and genetic algorithms (GAs) are observed to be very successful in dealing with such problems. In our study, a simple GA (SGA) and four hybrid GAs (HGAs) are proposed for the MSTSP. The SGA starts with initial population produced by sequential sampling approach that is improved by 2-opt search, and then it is tried to improve gradually the population through a proportionate selection procedure, sequential constructive crossover, and adaptive mutation. A stopping condition of maximum generation is adopted. The hybrid genetic algorithms (HGAs) include a selected local search and perturbation procedure to the proposed SGA. Each HGA uses one of three local search procedures based on insertion, inversion and swap operators directly or randomly. Experimental study has been carried out among the proposed SGA and HGAs by solving some TSPLIB asymmetric and symmetric instances of various sizes. Our computational experience reveals that the suggested HGAs are very good. Finally, our best HGA is compared with a state-of-art algorithm by solving some TSPLIB symmetric instances of many sizes. Our computational experience reveals that our best HGA is better.**

Keywords*—Hybrid genetic algorithm; maximum scatter travelling salesman problem; sequential constructive crossover; adaptive mutation; local search; perturbation procedure

I. INTRODUCTION

The travelling salesman problem (TSP) is a popular problem, which finds smallest tour of the salesman that starts journey from a headquarters city and visits all outstanding n cities (nodes) exactly once before comes back to his headquarters. The TSP is NP- Hard [1] and several good procedures are suggested to solve the problem. However, some circumstances need different constraints to accept a tour as solution. One such constraint is to maximize the shortest edge in the tour, and the TSP having such constraint is called the maximum scatter TSP (MSTSP). So, the MSTSP finds a Hamiltonian cycle/circuit so as to maximize the shortest edge. That means, each city in the Hamiltonian circuit is far from (scattered) its preceding and succeeding cities. The problem is also known as the max-min 1-neighbour TSP. In general, the max-min m-neighbour TSP aims to maximize the shortest edge (distance) between a city and its all m-neighbor cities in the Hamiltonian cycle/circuit. The bottleneck TSP (BTSP) is very close to the MSTSP. The BTSP aims to minimize the longest edge [2]. Further, the maximum TSP (MaxTSP) which finds a Hamiltonian cycle/circuit to maximize the length of any tour is also closely related to the MSTSP [3]. Fig. 1 shows the difference between TSP and MSTSP on an instance of 29 cities [4]. It is clear from the figure that the TSP aims to decrease the total distance covered by the salesman, whereas the MSTSP aims to maximize the shortest edge by producing any two successive cities in its tour as much scattered as possible.

Let us formally define the MSTSP as follows: Let a network with n cities (city 1 is the headquarters) and an nXn distance (time or cost, etc.) matrix $D=[d_{ij}]$ associated with ordered pair (i, j) of cities is given. Let $(1=\alpha_0, \alpha_1, \alpha_2, ..., \alpha_{n-1}, \alpha_n=1) \equiv \{1\to\alpha_1\to\alpha_2\to .... \to\alpha_{n-1}\to 1\}$ be a tour. The tour value is defined as $\min\{d_{\alpha_i,\alpha_{i+1}}: i = 0, 1, 2, \ldots, n-1\}$. The objective is to maximize the tour value.

The problem may be converted to the BTSP by supposing $c_{ij} = M-d_{ij}$, where $C = [c_{ij}]$ is the corresponding BTSP's distance (or cost) matrix and M is a big number [5]. The MSTSP was first defined in [6], which has several applications ([1], [7]). The MSTSP is NP-hard [1], and no polynomial-time algorithm is available for solving the problem. So, finding optimal solution for large-sized problem instances using exact method is not possible. Thus, for finding better solution, within acceptable computational effort, to such type of problems, generally, heuristic/metaheuristic algorithms are applied. Tabu search [8], simulated annealing [9], ant colony algorithm [10], insertion heuristic [11], variable neighbourhood method [12], discrete differential evolution algorithm [13], genetic algorithms [14], etc., are some popular metaheuristic algorithms. Among them, genetic algorithms (GAs) are widely used algorithms, and so, we are using GAs to solve the MSTSP.

GAs are based on simulating the Darwinian survival-of-the-fittest theory in the environmental biology [14]. They are very robust, parallel, and global search metaheuristics that can solve large-sized problems quickly. They can automatically obtain and collect knowledge throughout the search procedure

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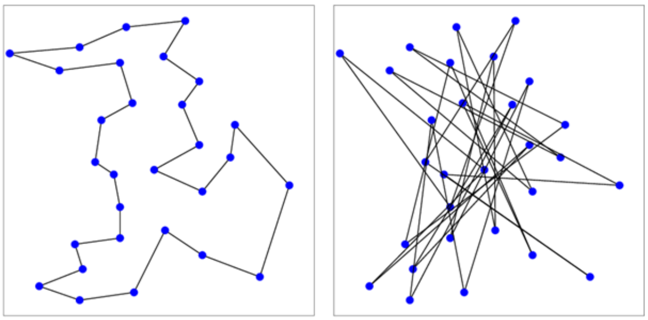
and can adaptively manage the search procedure to obtain the optimal/best solution. They were effectively applied to various complex optimization problems for solving them. For any problem, each feasible solution may be encoded as a string called chromosome or individual whose value is its objective function [15]. Chromosomes are collections of genes.



(a) TSP solution (b) MSTSP solution

Fig. 1. Difference between TSP and MSTSP.

Simple GAs start from a chromosome set known as initial population and then go through mainly three basic operators – selection, crossover, and mutation, to generate improved populations in following generations. Selection operator probabilistically copies some chromosomes to the following generation. Crossover arbitrarily selects two parent chromosomes and mates them to produce offspring chromosome(s). Mutation picks out a position at a chromosome randomly and changes its value. The crossover along with selection is the major procedure in GAs. Mutation varies the search space and defends genetic material losses. Thus, crossover probability is set to be very high, whereas mutation probability is set to be very low [14]. As crossover operator is very important operator, so, using better crossover operators can achieve better GAs. Normally, crossover methods that were applied for the usual TSP are applied to its variations also. A computational experience carried amongst eight crossover methods for the MSTSP proven that sequential constructive crossover is the best operator [16].

Though simple GAs using three basic operators can solve complex optimization problems quickly, but very often they converge prematurely, and get trapped in local minima [17]. So, one must apply some techniques to overcome premature convergence issue and to enhance the solution obtained by simple GAs. So, this paper develops a simple GA (SGA) and four hybrid GAs (HGA1, HGA2, HGA3 and HGA4) for finding solution to the MSTSP. Our proposed SGA uses sequential sampling algorithm along with 2-opt search for initial population generation, sequential constructive crossover, and adaptive mutation. The hybrid genetic algorithms (HGAs) include a selected local search and pertu`rbation procedure to the proposed SGA. Each HGA uses one of the local search procedures based on insertion, inversion, and swap operators. Generally, perturbation procedure is used to overcome premature convergence issue. The partially mapped crossover [15] along with swap mutation for perturbation procedure is to find better quality solution to the MSTSP.

The usefulness of our proposed HGAs have been examined amongst themselves and calculated percentage of improvement of the obtained solution over the solution obtained by SGA for the asymmetric and symmetric TSPLIB problem instances. The experimental results show a very good improvement of the solutions by HGAs over the solutions by SGA. Further, it is seen that for asymmetric instances, HGA3 is placed in 2nd position and HGA4 is the best one. For symmetric instances, HGA2 is placed in 2nd position and HGA4 is the best one. Overall, for both categories of the instances, HGA4 is the best one, HGA2 is the 2nd best and HGA3 is the 3rd best. Finally, our HGA4 is compared against multi-start iterated local search (MS-ILS(h1+h2)) [4] by solving some TSPLIB symmetric instances of different sizes. Our computational experience reveals that our HGA4 is better than MS-ILS(h1+h2).

This paper is arranged as follows: A literature survey for the MSTSP is provided in Section II. Section III develops simple and hybrid GAs for the problem, while Section IV reports computational experience of the developed algorithms. Finally, Section V provides conclusion and forthcoming research works.

II. Literature Review

The MSTSP is a difficult NP-hard problem. Methods to solve this kind of optimization problems are grouped into two broad groups – exact and heuristic methods ([18]-[19]). There are very less literatures on the MSTSP. The first procedure for solving the problem is developed by Arkin et al. [1]. They proved that the MSTSP is NP-hard, and no constant-factor approximation procedure can be devised unless NP = P. A factor-2 (claimed to be best) approximation procedure is developed for max-min 1-neighbour TSP satisfying the triangle inequality for path and cycle adaptations. Further, they developed procedures for the max-min 2-neighbour TSP satisfying triangle inequality for cycle and path adaptations. Finally, the procedures extended to find an approximation solution of the max-min m-neighbour TSP for path version.

Approximation procedures for max-min 2-neighbour TSP with triangle inequality was developed by Chiang [20] for the cycle and path adaptations by improving the procedures in [1]. As reported, both procedures are very simple. Some studies on the MSTSP and its related versions are reported by John [7].

An approximation procedure for the MSTSP satisfying triangle inequality was developed by Kabadi and Punnen [21] that claimed to find the best bound for this case.

An improved procedure of the procedure in [1] was proposed for the points on a line to a regular mXn-grid by Hoffmann et al. [22] that claimed to obtain optimal solutions. They further claimed that the procedure takes linear computational effort to obtain optimal tour in some cases.

The multi-salesmen MSTSP called multiple MSTSP (MMSTSP) was proposed by Dong et al. [23]. They proposed three improved GAs for the problem. Their improved algorithms used greedy initialization, simulated annealing, and hill-climbing algorithms. As reported, their algorithms are effective algorithms that can expose various characteristics to find solution of the problem.

In [4], a multi-start iterated local search procedure was developed for the MSTSP. Based on modified 2-opt moves and insertion, two local search procedures were proposed in their procedure. As reported, their algorithm found very good results on some symmetric TSPLIB instances.

In [16], eight GAs were developed using eight crossover methods for the MSTSP. A comparative study was reported on some TSPLIB asymmetric and symmetric instances. It was showed that the sequential constructive crossover (SCX) is the best, partially mapped crossover (PMX) is the second-best and greedy crossover (GX) is the worst.

It is mentioned that the BTSP is very close to the MSTSP. Lexisearch approaches were developed for the BTSP in ([24], [25]). Further hybrid algorithms were developed for the BTSP in ([26], [27]). The MaxTSP is also close to the MSTSP for which a hybrid GA is developed for finding solution to the problem [28].

Since there are a few literature on the hybrid algorithms on the MSTSP, hence we propose to develop hybrid genetic algorithms to show the efficiency of the hybrid algorithms in solving the problem.

III. Hybrid Genetic Algorithms for the MSTSP

Genetic algorithms (GAs) are established to be effective for the traditional TSP and its some variants. Though they do not assure the optimality of their obtained solutions, they normally obtain very close optimal solutions rapidly. In this section, we develop a simple GA (SGA) and four hybrid GAs (HGAs) for the MSTSP.

A. Chromosome Representation

The first job in GAs is to determine a chromosome representation procedure for representing solutions of a problem so that GA operators can produce feasible chromosome(s). For TSP and its variants, mainly path representation is used which lists cities so that no city is duplicated in a chromosome. We consider this path representation for the MSTSP. As an example, let {1, 2, 3, 4, 5, 6, 7, 8} be the cities in an 8-city problem, and the chromosome (1, 3, 2, 7, 8, 6, 4, 5) denotes the tour {1→3→2→7→8→6→4→5 →1} whose objective as well as fitness function is the shortest edge in this tour. As MSTSP is a maximization problem, a higher fitness value is better than the lower fitness value.

B. Improved Initial Population

Starting with an improved initial population can provide good solutions quickly. We use sequential sampling approach [26] for generating initial population for our GAs, that was successfully applied on other TSP variants ([27]-[28]). In sequential sampling approach, first alphabet table is constructed based on the given distance (cost) matrix, then the probability of visiting every un-visited city is allocated in each row such that first un-visited city is allocated higher probability than probability of 2nd city, then 2nd one is allocated higher than the 3rd city, and so forth. For each un-visited city in that row, cumulative probability is also calculated. The city is accepted that represents a randomly generated number in a cumulative probability interval. This process is repeated until a valid chromosome is created. This way, a population of given size is generated. However, it is observed that this approach cannot search all space. So, to improve the initial population, we apply 2-opt search to every chromosome for enhancing the population. However, if the newly obtained chromosome is better than the old one, replace it by the new one, otherwise, no action is taken. Due to the strong capability of 2-opt local search, it can improve the search space of our proposed algorithm.

C. Selection Strategy

The selection strategy is the procedure of choosing parents from the current population for the next operation. In selection operation, no new chromosome is created, only some of the fitter chromosomes are passed to the breeding pool for the subsequent operation/generation. By selecting a greater section of fitter chromosomes, this operation simulates the Darwinian hypothesis of survival-of-the-fittest in biology. Normally, the proportionate selection is used where a chromosome is chosen depending on its probability of selection. We use stochastic remainder selection procedure [29] for the proposed GAs. In this procedure, first 'expected count' of every individual is computed by dividing their corresponding fitness value with the average fitness value. Then as many individuals are copied equal to the mantissa of the expected counts, and then mantissas are subtracted from the corresponding expected counts. This will result the values of the expected counts less than one. If a randomly generated number is less than the expected count of a selected individual, then the individual is inserted into the mating pool. Repeat this procedure till the number of chromosomes is equal to the size of population. Note that population size is the number of chromosomes in the population.

D. Crossover Operator

Crossover operator performs a very big role in GAs, where two parent chromosomes as well as a crossover point within the chromosomes' length are chosen and the chromosomes' data after the crossover point are exchanged. Quite a few good crossover methods are available in the literature for traditional TSP that might be applied for the MSTSP. Ahmed [16] applied eight crossover operators, namely, ordered crossover [30], partially mapped crossover [31], cycle crossover [32], alternating edges crossover [33], generalized N crossover [34], greedy crossover [33], edge recombination crossover [35], sequential constructive crossover [15] on the MSTSP, and reported a comparative study among them. As reported, sequential constructive crossover (SCX) is observed as the best method. We also apply this SCX in our proposed GAs. The steps of SCX algorithm are as follows [16]:

Step 1: Start from 'city 1' (i.e., current city p =1).

Step 2: Search sequentially both parent chromosomes and take the first un-visited city emerged after 'city p' in the parents. If no un-visited city after 'city p' is available in a parent chromosome, search from beginning of the chromosome and take the first un-visited city and go to Step 3.

Step 3: Suppose 'city α' and 'city β' are in 1st and 2nd parents correspondingly, then for choosing the following city go to Step 4.

Step 4: If $d_{p\alpha} > d_{p\beta}$, then choose 'city α', otherwise, 'city β' as subsequent city and merge it to the current offspring. If the offspring is a full chromosome, stop, else, the current city is renamed as 'city p', go to Step 2.

Let us illustrate the SCX using a 7-city instance with distance matrix provided in Table I. Let P_1: (1, 5, 3, 2, 7, 4, 6) and P_2: (1, 5, 7, 3, 6, 2, 4) be parent chromosomes with costs 3 and 2 respectively. Our computation is started from the city 1 (headquarters).

TABLE I. THE DISTANCE MATRIX

City	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	0	7	15	9	10	6	8
2	11	0	8	7	11	3	6
3	15	5	0	16	12	5	8
4	2	5	11	0	9	13	14
5	8	6	3	5	0	6	7
6	6	13	8	11	5	0	5
7	5	15	3	7	12	6	0

After city 1, city 5 in both P_1 and P_2 is the un-visited city, city 5 is added that produces the offspring as (1, 5). After city 5, cities 3 in P_1 and 7 in P_2 are un-visited cities with costs c_{53}=3 and c_{57}=7. Since $c_{57}>c_{53}$, city 7 is added that produces the offspring as (1, 5, 7). After city 7, cities 4 in P_1 and 3 in P_2 are un-visited cities with costs c_{74}=7 and c_{73}=3. Since $c_{74}>c_{73}$, city 4 is added that produces the offspring as (1, 5, 7, 4). After city 4, city 6 in P_1 with costs c_{46}=13, but no city in P_2. So, for P_2, search from the beginning and finds un-visited city 3 with c_{43}=11. Since $c_{46}>c_{43}$, city 6 is added that produces the offspring as (1, 5, 7, 4, 6). After city 6, no city is present in P_1 and un-visited city 2 is present in P_2 with cost c_{62}=13. So, for P_1 search from the beginning and finds un-visited city 3 with c_{63}=8. Since $c_{62}>c_{63}$, city 2 is added that produces the offspring as (1, 5, 7, 4, 6, 2). Finally, after city 2, the only remaining city is 3, which is added that produces the offspring as (1, 5, 7, 4, 6, 2, 3) with cost 7 is obtained. Fig. 2 shows parents (P1 and P2) and offspring (O) chromosomes. In general, the crossover operator which preserves better characteristics of parents in their children is expected to be better, and SCX is expected to be better in this regard. In Fig. 2(c), bold five edges are from either parent.

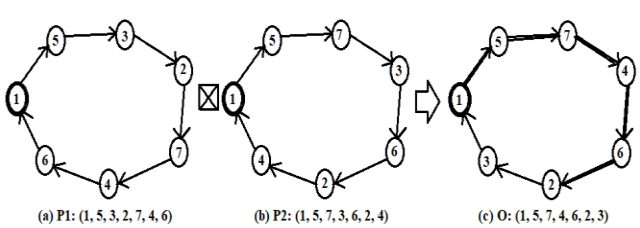


Fig. 2. Result of SCX Operation for the MSTSP.

Though SCX is observed as the best method, however, sometimes it creates bad offspring. So, to maintain a mixture of offspring and parent in a population, we replace the 1st parent by the offspring if it is better. In addition, the 2-opt local search is used on the better offspring to improve it further. Since the SCX operator produces only an offspring. So, to keep population size same in all generations, when selecting next pair for crossover, the present 2nd chromosome will be selected as the 1st parent and the 3rd chromosome will be as the 2nd parent, and so forth.

E. Mutation Operator

As some weaker chromosomes are omitted in selection and crossover processes in any generation, so, there might be some stronger chromosomes' structures which were lost forever. So, normally, mutation is applied to regain them. In traditional mutation operations, a gene (position) is chosen arbitrarily in a chromosome, then alters its subsequent allele (city). Some of the mutation operators are inversion mutation, insertion mutation, swap mutation, adaptive mutation [36]. The adaptive mutation is implemented for our GAs. To perform this mutation, the information from the chromosomes in a population are gathered to identify a structure amongst them. If mutation is to be performed, then the chromosomes which do not match the structure would be muted. The steps of adaptive mutation are as follows:

Step 1: In the current population, take all chromosomes.

Step 2: Construct a one-dimensional array of order n, let A, by adding a city which appears least time in the present position of all chromosomes.

Step 3: If the mutation is allowed, two genes are selected arbitrarily so that they are not same in the subsequent positions of the array, A, then they are exchanged.

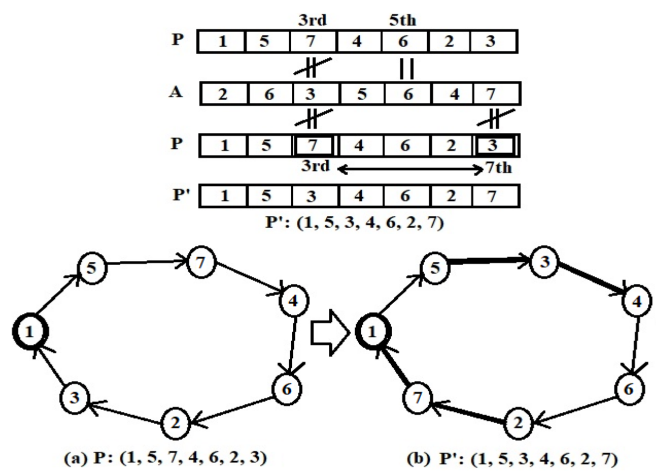


Fig. 3. Result of Adaptive Mutation Operation for the MSTSP.

Since the city 1 is always fixed in the 1st position, we exclude the 1st position as well as the city 1 in this procedure. For example, suppose the chromosome P: (1, 5, 7, 4, 6, 2, 3) is chosen for mutation operation, and the array be A: [2, 6, 3, 5, 6, 4, 7]. Let 3rd and 5th positions are chosen arbitrarily. The 3rd position's gene '7' is same as the subsequent element in A, but 5th position's gene '6' is same as the subsequent element in A. So, we choose another position arbitrarily and let, 7th position is chosen that allows the swap. Hence, the mutated chromosome would be P': (1, 5, **3**, 4, 6, 2, **7**) that is showed in Fig. 3. New edges in the muted chromosome are shown in boldfaces in Fig. 3(b).

F. Local Search

There are various local search procedures presented in the literature, amongst them combined mutation is seen as a nice local search procedure ([2], [27], [28]). It merges insertion, inversion, and swap mutations with 1.00 probabilities. Insertion mutation selects a city in a chromosome, then inserts into an arbitrary position. Inversion mutation selects two positions in a chromosome, then inverts the sub-chromosome between them. Swap mutation selects two cities (genes) arbitrarily and exchanges them. We define these three mutations as local search procedures in our HGA as follows.

1) Insertion search: Suppose (α_1, α_2, α_3, ..., α_n) be a chromosome. The insertion search may be defined as:

Step 0: For i: = 2 to n-1 perform the next step.

Step 1: For j: = i+1 to n perform the next step.

Step 2: If inserting city α_i after city α_j improves the assignment cost, then insert the city α_i after the city α_j.

2) Inversion search: Suppose (α_1, α_2, α_3, ..., α_n) be a chromosome. The inversion search may be defined as:

Step 0: For i: = 2 to n-1 perform the next step.

Step 1: For j: = i+1 to n perform the next step.

Step 2: If inverting sub-chromosome between the cities α_i and α_j improves the assignment cost, then invert the sub-chromosome.

3) Swap search: Suppose (α_1, α_2, α_3, ..., α_n) be a chromosome. The swap search may be defined as:

Step 0: For i: = 2 to n-1 perform the next step.

Step 1: For j: = i+1 to n perform the next step.

Step 2: If exchanging cities α_i and α_j improves the assignment cost, then swap them.

In our local search procedure, one of these three local search is selected for our HGA for the problem.

G. Perturbation Procedure

Though GAs are very good methods, but sometimes, they get stuck in local optima. This may be due to identical population, and so, the population must be varied. Perturbation procedure is useful in escaping from local optima. If (Best Solution – Average Solution) < 0.10*Best Solution, then we apply partially mapped crossover (PMX), swap mutation and combined mutation operators. The PMX selects two crossover points, describes swap mappings in the segment between these points, and delivers two offspring. Further, mutation can assist other operators to beat local optima issue and thus, can find better solutions.

H. Hybrid GAs

In our study, a simple genetic algorithm (SGA) and four hybrid genetic algorithms (HGAs) are proposed for the MSTSP. The SGA starts with initial population generated by sequential sampling approach which is further improved by 2-opt search, and it is tried to improve gradually the population through stochastic remainder selection, sequential constructive crossover, and adaptive mutation. A stopping condition of maximum generation is adopted. The hybrid genetic algorithms (HGAs) include a selected local search and perturbation procedure to the proposed SGA. When the stopping condition is satisfied, near-optimal solution is produced. The selected local search defines each proposed HGA as follows:

HGA1: Insertion search,

HGA2: Inversion search,

HGA3: Swap search, and

HGA4: Randomly selected one of three local searches – insertion, inversion, and swap search.

The common structure of our proposed HGAs is presented in Fig. 4.

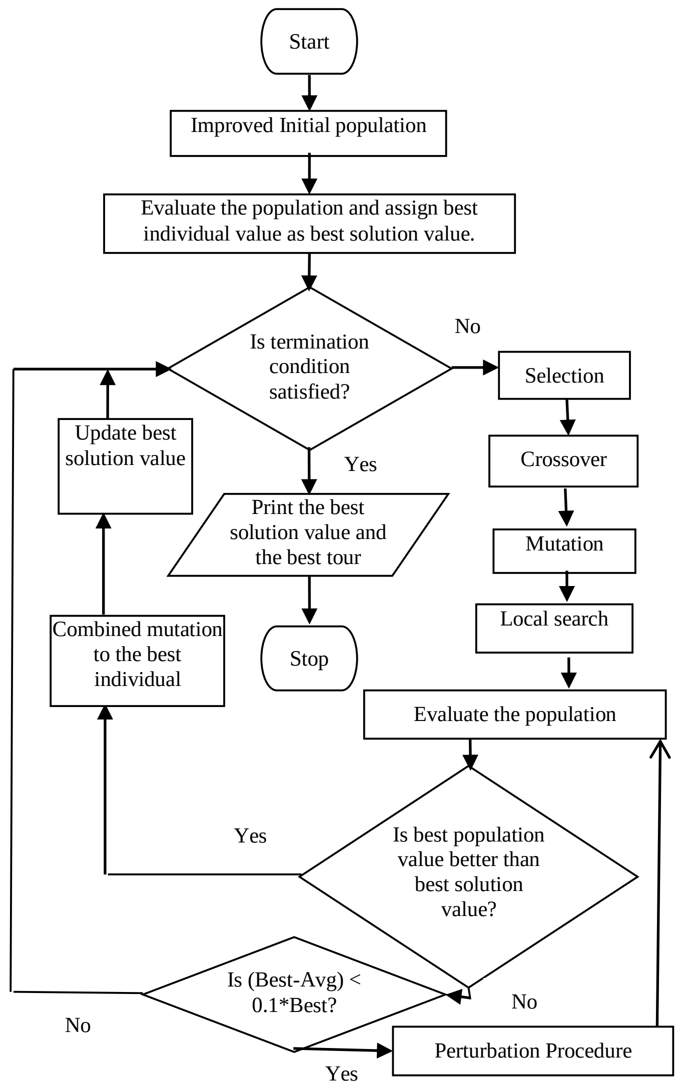


Fig. 4. Flow-Chart of our Proposed HGAs.

IV. Computational Experience

We encoded our proposed SGA and HGAs in Visual C++. To determine the value of HGAs, computational experience is performed on some typical TSPLIB instances [37] of many sizes and then implemented on a Laptop with i7-1065G7 CPU@1.30 GHz and 8 GB RAM under MS Windows 10. We run GAs for separate parameter settings, and chosen parameters are recorded in Table II.

TABLE II. Comparative Study of SGA and HGAs for Asymmetric TSPLIB Instances

Instance	n	Result	SGA	HGA1	HGA2	HGA3	HGA4
ftv33	34	Best Sol	142	**143**	**143**	**143**	**143**
		Avg. Sol	134.45	**143.00**	**143.00**	**143.00**	**143.00**
		S.D.	4.25	0.00	0.00	0.00	0.00
		Avg. Time	0.08	0.16	0.16	0.08	0.14
		Avg. Imp(%)		6.36	6.36	6.36	6.36
ftv35	36	Best Sol	151	**154**	**154**	**154**	**154**
		Avg. Sol	141.50	**154.00**	**154.00**	**154.00**	**154.00**
		S.D.	5.35	0.00	0.00	0.00	0.00
		Avg. Time	0.39	0.78	0.86	0.71	0.78
		Avg. Imp(%)		8.83	8.83	8.83	8.83
ftv38	39	Best Sol	151	**154**	**154**	**154**	**154**
		Avg. Sol	140.00	**152.20**	151.00	151.20	152.00
		S.D.	6.42	2.65	3.32	3.43	2.80
		Avg. Time	0.90	1.40	1.18	1.13	1.02
		Avg. Imp(%)		8.71	7.86	8.00	8.57
p43	43	Best Sol	16	**17**	**17**	**17**	**17**
		Avg. Sol	13.20	**17.00**	**17.00**	**17.00**	**17.00**
		S.D.	0.30	0.00	0.00	0.00	0.00
		Avg. Time	0.98	1.32	1.30	1.17	1.04
		Avg. Imp(%)		28.79	28.79	28.79	28.79
ftv44	45	Best Sol	156	**162**	**162**	**162**	**162**
		Avg. Sol	145.25	161.20	161.50	**161.60**	**161.60**
		S.D.	7.10	1.60	1.50	1.20	1.20
		Avg. Time	0.94	1.55	1.43	1.57	1.60
		Avg. Imp(%)		10.98	11.19	11.26	11.26
ft47	48	Best Sol	162	**168**	**168**	**168**	**168**
		Avg. Sol	150.15	167.70	167.80	**167.90**	167.80
		S.D.	6.40	0.46	0.40	0.30	0.40
		Avg. Time	1.02	1.77	1.86	1.93	1.87
		Avg. Imp(%)		11.69	11.75	11.82	11.75
ry48p	48	Best Sol	1176	**1232**	**1232**	**1232**	1227
		Avg. Sol	1140.00	1211.40	1215.60	**1217.40**	1217.20
		S.D.	22.49	17.77	14.61	15.49	16.83
		Avg. Time	1.07	1.42	1.90	1.99	1.97
		Avg. Imp(%)		6.26	6.63	6.79	6.77
ft53	53	Best Sol	360	**379**	**379**	**379**	**379**
		Avg. Sol	345.70	376.00	**378.00**	376.50	376.50
		S.D.	12.52	2.45	2.00	2.50	2.50
		Avg. Time	1.52	1.74	2.02	1.97	1.99
		Avg. Imp(%)		8.76	9.34	8.91	8.91
ftv55	56	Best Sol	143	**154**	**154**	**154**	**154**
		Avg. Sol	132.60	151.60	152.80	153.60	**153.90**
		S.D.	8.01	3.75	2.14	0.92	0.30
		Avg. Time	1.73	2.02	2.18	2.09	2.19
		Avg. Imp(%)		14.33	15.23	15.84	16.06
ftv64	65	Best Sol	143	**160**	158	**160**	**160**
		Avg. Sol	132.30	154.20	153.60	153.60	**158.00**
		S.D.	6.08	3.19	3.07	5.39	2.00
		Avg. Time	1.78	2.70	2.54	2.52	2.54
		Avg. Imp(%)		16.55	16.10	16.10	19.43
ft70	70	Best Sol	926	973	972	**974**	**974**
		Avg. Sol	893.70	964.50	964.90	**967.40**	965.60
		S.D.	19.02	6.38	7.05	8.46	10.58
		Avg. Time	1.93	2.89	2.91	3.04	3.08
		Avg. Imp(%)		7.92	7.97	8.25	8.05
ftv70	71	Best Sol	147	160	161	160	**161**
		Avg. Sol	133.50	156.00	157.00	**157.60**	**157.60**
		S.D.	10.25	2.90	2.83	1.96	2.42
		Avg. Time	1.81	2.82	2.93	2.97	3.15
		Avg. Imp(%)		16.85	17.60	18.05	18.05
kro124p	100	Best Sol	2224	**2347**	**2347**	**2347**	**2347**
		Avg. Sol	2153.40	2345.10	**2347.00**	**2347.00**	**2347.00**
		S.D.	65.66	5.70	0.00	0.00	0.00
		Avg. Time	2.16	3.42	3.40	3.58	3.65
		Avg. Imp(%)		8.90	8.99	8.99	8.99
ftv170	171	Best Sol	146	172	170	172	**174**
		Avg. Sol	128.20	169.20	167.60	170.67	**171.67**
		S.D.	7.67	2.77	3.65	2.31	2.23
		Avg. Time	5.10	7.52	7.91	7.57	7.95
		Avg. Imp(%)		31.98	30.73	33.13	32.35
rbg323	323	Best Sol	14	**20**	19	**20**	**20**
		Avg. Sol	12.20	18.36	17.92	**18.73**	18.56
		S.D.	0.60	1.12	0.60	1.01	1.26
		Avg. Time	8.30	15.23	13.22	14.75	15.73
		Avg. Imp(%)		50.49	46.89	53.52	47.54
rbg358	358	Best Sol	16	**18**	**18**	**18**	**18**
		Avg. Sol	13.50	17.20	17.60	17.60	**17.71**
		S.D.	1.32	1.10	0.89	0.89	0.76
		Avg. Time	9.57	19.21	17.56	18.78	18.43
		Avg. Imp(%)		27.41	30.37	30.37	31.19
rbg403	403	Best Sol	15	15	16	**16**	**16**
		Avg. Sol	13.40	15.00	15.20	**15.29**	**15.29**
		S.D.	1.20	0.00	0.45	0.49	0.49
		Avg. Time	12.49	22.33	23.26	25.03	25.23
		Avg. Imp(%)		11.94	13.43	14.10	14.10

Fig. 5 shows solutions for ftv170 (only 100 generations are considered) by SGA and HGAs. Each curvature is for only one GA that shows progress of the solution in consecutive generations. The figure indicates some good variations of HGA4 and proves that HGA4 is the top. HGA3 also has certain variations that are placed in 2nd place. But SGA has no variations at all after few generations, get stuck in local maximum so rapidly and is proven to be the worst.

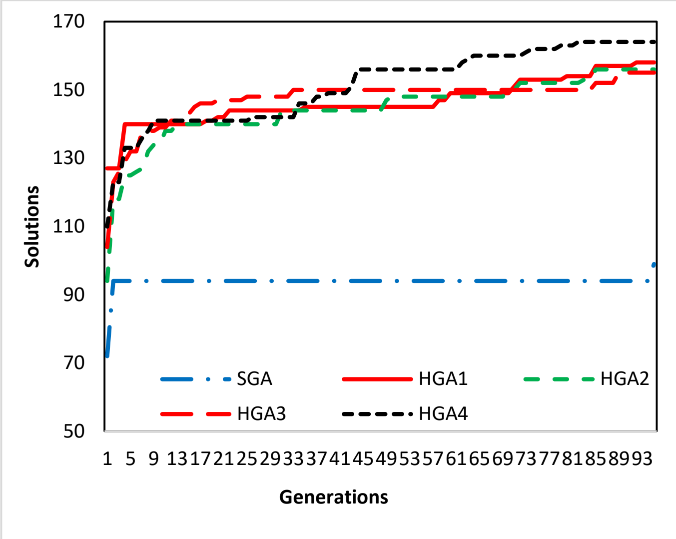


Fig. 5. Solutions by SGA and HGAs for ftv170.

Comparative studies among SGA and HGAs on some TSPLIB asymmetric and symmetric instances are reported in Tables III and V, respectively. We record best solution (Best Sol), average solution (Avg. Sol), standard deviation (S.D) of the solutions, and average computational time (Avg. Time) (in seconds) for each problem instance in the tables. The best results are indicated by boldfaces. The tables further report average improvement (%) of the average solution by HGAs over the average solution by SGA using the following formula:

$$\text{Avg. Imp}(\%) = 100(S_1 - S_2)/S_2 ,$$

where S_1 and S_2 are average solutions by a HGA and the SGA, respectively.

The Table III summarizes the results of asymmetric instances of sizes from 34 to 403. From the table, it is observed that the SGA could not find either best solution or best average solution for any instance. All four HGAs together obtained best average solutions with least S.D. for three instances ftv33, ftv35 and p43. In addition, HGA2, HGA3 and HGA4 together obtained best average solutions with lowermost S.D. for the instance kro124p; HGA3 and HGA4 together obtained best average solutions for ftv44, ftv70 and rbg403; HGA1 obtained best average solution with least S.D. for the instance ftv38; HGA2 obtained best average solution with lowest S.D. for the instance ft53; HGA3 obtained best average solutions for ftv47, ry48p, ft70 and rbg323; HGA4 obtained best average solutions with least S.D. for the instances ftv55, ftv64, ftv170 and rbg358. From this experiment we can say that HGA3 and HGA4 are competing, however, HGA4 is observed as the best algorithm.

By looking at the average improvement (%) of the average solutions by HGAs, we have the same conclusion. The average improvements (%) are shown in Fig. 6 that also indicates the suitability of the HGAs, specially HGA3 and HGA4. Looking at the overall results on the asymmetric instances, one can decide that the HGA4 is the best one and HGA3 is the 2nd best one.

TABLE III. PARAMETERS FOR ALL GAS

Parameters	**Values**
Population size	50
Crossover probability	100%
Mutation probability	9%
Termination criterion	For SGA, 2000 generations For HGAs, 200 generations
No. of runs for each instance	20 times

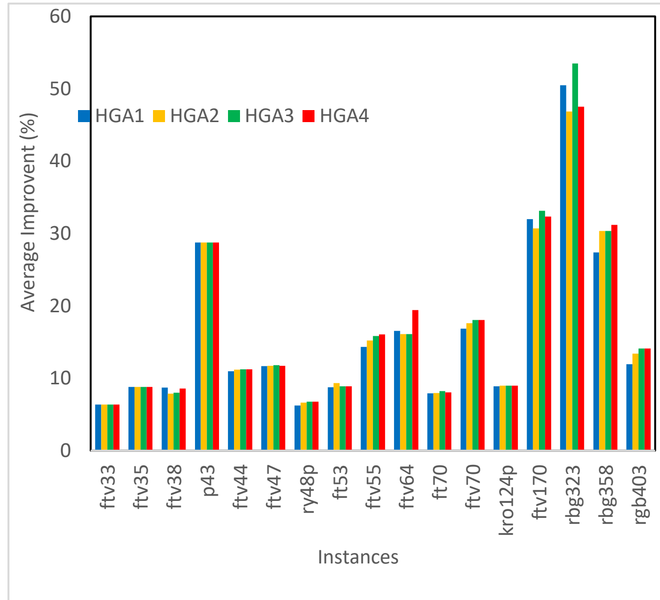


Fig. 6. Average Improvement (%) of Solutions by different HGAs over SGA for Asymmetric Instances.

It is very apparent from the above experiments that HGAs have very good improvements in the solutions over SGA for the TSPLIB asymmetric instances. HGA4 is observed as the best algorithm and SGA is the worst. Now, to verify whether average solutions obtained by HGA4 is significantly and statistically different from the average solutions obtained by remaining HGAs, Student's t-test is conducted using following formula [38]. It may be noted that 20 runs have been conducted for each instance.

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{SD_1^2}{n_1 - 1} + \frac{SD_2^2}{n_2 - 1}}}$$

where,

$\bar{X}_1 - average\ of\ first\ sample,$

$SD_1 - standard\ deviation\ of\ first\ sample,$

$\bar{X}_2 - average\ of\ second\ sample,$

$SD_2 - standard\ deviation\ of\ second\ sample,$

$n_1 - first\ sample\ size,$

$n_2 - second\ sample\ size,$

Here, $\bar{X}_2$ and SD_2 values are obtained by HGA4, and $\bar{X}_1$ and SD_1 values are obtained by other HGAs.

The t-statistic results are provided in Table IV. The t-values may be negative or positive. As the MSTSP is a maximization problem, negative value indicates that HGA4 obtained better solution than its competitive HGA, and positive value indicates that the competitive HGA obtained better solution than HGA4. Here 95% confidence level ($t_{0.05}$ = 1.73) is applied, so, if t-value is bigger than 1.73, their difference is significant. In this condition if t-value is negative then HGA4 is better, else competitive HGA is better. If t-value is smaller than 1.73, then they have no statistical and significant difference. The table further reports the name of the better HGA.

TABLE IV. THE T-VALUES AGAINST HGA4 AND THE RESULT ABOUT HGAS THAT OBTAINED SIGNIFICANTLY BETTER SOLUTIONS FOR THE TSPLIB ASYMMETRIC INSTANCES

Instance	HGA1	HGA2	HGA3	Instance	HGA1	HGA2	HGA3
ftv33	---	---	---	ftv64	-7.06	-8.41	-5.36
Better	---	---	---	Better	**HGA4**	**HGA4**	**HGA4**
ftv35	---	---	---	ft70	-0.62	-0.39	0.93
Better	---	---	---	Better	---	---	---
ftv38	0.36	-1.61	-1.26	ftv70	-2.97	-1.13	0.00
Better	---	---	---	Better	**HGA4**	---	---
p43	---	---	---	kro124p	-2.33	---	---
Better	---	---	---	Better	**HGA4**	---	---
Ftv44	-1.40	-0.36	0.00	ftv170	-4.86	-6.66	-2.18
Better	---	---	---	Better	**HGA4**	**HGA4**	**HGA4**
ftv47	-1.15	0.00	1.40	rbg323	-0.83	-3.21	0.74
Better	---	---	---	Better	---	**HGA4**	---
ry48p	-1.66	-0.50	0.06	rbg358	-2.67	-0.66	-0.66
Better	---	---	---	Better	**HGA4**	---	---
ft53	-1.00	3.28	0.00	rbg403	-4.14	-0.95	0.00
Better	---	**HGA2**	---	Better	**HGA4**	---	---
ftv55	-4.28	-3.56	-2.17				
Better	**HGA4**	**HGA4**	**HGA4**				

On ten instances, HGA4 and HGA1 have no significant and statistical difference. On the other seven instances HGA4 is better than HGA1. On twelve instances, HGA4 and HGA2 have no significant and statistical difference. On the instance ft53, HGA2 is better than HGA4, and on the remaining four instances HGA4 is better than HGA2. On fourteen instances, HGA4 and HGA3 have no significant and statistical difference, and on the remaining three instances, HGA4 is better than HGA3. On all seventeen instances, HGA4 is found better than other HGAs. From this experiment we can say that HGA4 is the best for asymmetric instances.

The Table V summarizes the results of symmetric instances of sizes from 21 to 318. From the table, it is observed that the SGA could obtain best solution for only the instance gr21. All HGAs obtained best average solutions with lowest S.D. for four instances gr21, fri26, bayg29 and berlin52. In addition, HGA2 and HGA4 together obtained best average solutions with lowest S.D. for the instances kroA150 and a280; HGA3 and HGA4 together obtained best average solutions with lowest S.D. for the instance si175; HGA2 obtained best average solutions for three instances - gr48, st70 and pr76; HGA3 obtained best average solutions for the instance dantzig42; HGA4 obtained best average solutions for five instances - eil51, lin105, ch130, d198, pr226 and lin318. From this study we can say that HGA4 is the best one.

TABLE V. COMPARATIVE STUDY OF SGA AND HGAS FOR SYMMETRIC TSPLIB INSTANCES

Instance	n	Result	SGA	HGA1	HGA2	HGA3	HGA4
gr21	21	Best Sol	**370**	**370**	**370**	**370**	**370**
		Avg. Sol	368.75	**370.00**	**370.00**	**370.00**	**370.00**
		S.D.	4.44	0.00	0.00	0.00	0.00
		Avg. Time	0.00	0.01	0.00	0.01	0.00
		Avg. Imp(%)		0.34	0.34	0.34	0.34
fri26	26	Best Sol	100	**102**	**102**	**102**	**102**
		Avg. Sol	93.80	**102.00**	**102.00**	**102.00**	**102.00**
		S.D.	2.60	0.00	0.00	0.00	0.00
		Avg. Time	0.05	0.06	0.05	0.06	0.05
		Avg. Imp(%)		8.74	8.74	8.74	8.74
bayg29	39	Best Sol	182	**189**	**189**	**189**	**189**
		Avg. Sol	167.40	**189.00**	**189.00**	**189.00**	**189.00**
		S.D.	9.14	0.00	0.00	0.00	0.00
		Avg. Time	0.06	0.08	0.07	0.08	0.07
		Avg. Imp(%)		12.90	12.90	12.90	12.90
dantzig42	42	Best Sol	69	**73**	**73**	**73**	**73**
		Avg. Sol	63.15	71.30	71.30	**73.00**	72.80
		S.D.	2.57	0.71	0.71	0.00	0.71
		Avg. Time	0.90	1.28	1.25	1.15	1.07
		Avg. Imp(%)		12.91	12.91	15.60	15.28
gr48	48	Best Sol	515	558	**559**	558	558
		Avg. Sol	486.00	553.00	**558.00**	554.70	557.90
		S.D.	13.54	7.27	0.45	6.36	0.30
		Avg. Time	1.06	1.56	1.58	1.61	1.47
		Avg. Imp(%)		13.79	14.81	14.14	14.79
eil51	51	Best Sol	33	38	38	38	**39**
		Avg. Sol	30.15	37.20	37.70	37.70	**39.00**
		S.D.	1.77	0.84	0.64	0.64	0.00
		Avg. Time	1.13	1.56	1.49	1.90	1.55
		Avg. Imp(%)		23.38	25.04	25.04	29.35
berlin52	52	Best Sol	504	**541**	**541**	**541**	**541**
		Avg. Sol	466.55	**541.00**	**541.00**	**541.00**	**541.00**
		S.D.	16.90	0.00	0.00	0.00	0.00
		Avg. Time	1.54	1.77	1.84	1.67	1.80
		Avg. Imp(%)		15.96	15.96	15.96	15.96
st70	70	Best Sol	57	**63**	**63**	**63**	**63**
		Avg. Sol	52.00	59.55	**62.48**	60.10	62.25
		S.D.	2.88	1.56	1.43	1.30	1.22
		Avg. Time	1.88	2.02	2.10	2.04	2.09
		Avg. Imp(%)		14.52	16.31	15.58	15.87

pr76	76	Best Sol	8698	**9214**	**9214**	**9214**	**9214**
		Avg. Sol	7852.20	9085.60	**9169.90**	9043.65	9126.15
		S.D.	633.96	156.30	80.83	185.41	93.28
		Avg. Time	1.99	2.76	2.85	2.59	2.62
		Avg. Imp(%)		15.71	16.78	15.17	16.22
lin105	105	Best Sol	1270	1460	**1474**	**1474**	**1474**
		Avg. Sol	1173.85	1455.15	1466.35	1452.40	**1469.65**
		S.D.	83.07	8.76	5.72	12.46	8.16
		Avg. Time	2.14	3.65	3.78	3.89	3.98
		Avg. Imp(%)		23.54	24.92	23.73	25.20
ch130	130	Best Sol	395	454	455	457	**458**
		Avg. Sol	355.30	450.80	448.30	452.55	**458.00**
		S.D.	20.58	6.96	7.09	5.02	0.00
		Avg. Time	2.61	4.18	3.94	4.07	4.20
		Avg. Imp(%)		26.88	26.18	27.37	28.91
kroA150	150	Best Sol	1818	2147	**2153**	**2153**	**2153**
		Avg. Sol	1733.65	2132.50	**2153.00**	2137.29	**2153.00**
		S.D.	65.91	10.02	0.00	21.02	0.00
		Avg. Time	2.91	4.43	4.51	4.83	4.89
		Avg. Imp(%)		23.01	24.19	23.28	24.19
si175	175	Best Sol	276	296	**304**	**304**	**304**
		Avg. Sol	243.52	287.35	285.56	**304.00**	**304.00**
		S.D.	29.51	10.25	12.63	0.00	0.00
		Avg. Time	5.18	8.21	8.12	8.78	8.06
		Avg. Imp(%)		9.79	17.26	24.84	24.84
d198	198	Best Sol	643	731	735	731	**738**
		Avg. Sol	571.80	721.50	729.10	717.20	**738.00**
		S.D.	28.81	10.07	9.84	14.41	0.00
		Avg. Time	5.58	8.79	8.63	8.07	8.77
		Avg. Imp(%)		26.18	27.51	25.43	29.07
pr226	226	Best Sol	8070	9301	9357	9353	**9360**
		Avg. Sol	7811.40	9201.30	9272.90	9256.10	**9360.00**
		S.D.	72.12	104.91	15.94	58.74	0.00
		Avg. Time	6.23	10.73	10.83	9.91	10.75
		Avg. Imp(%)		17.79	18.71	18.49	19.82
a280	280	Best Sol	101	145	**148**	145	**148**
		Avg. Sol	93.62	144.40	**148.00**	135.30	**148.00**
		S.D.	7.85	4.03	0.00	2.00	0.00
		Avg. Time	7.85	13.02	13.09	13.03	13.10
		Avg. Imp(%)		54.24	58.09	44.52	58.09
lin318	318	Best Sol	1870	2351	**2395**	2375	**2395**
		Avg. Sol	1654.55	2351.50	2387.20	2361.30	**2388.10**
		S.D.	137.45	17.66	10.48	32.33	10.25
		Avg. Time	9.10	16.95	15.23	15.42	15.24
		Avg. Imp(%)		42.12	44.28	42.72	44.34

By looking at the average improvement (%) of the average solutions by HGAs, we can have the same conclusion. These results are shown in Fig. 7 that also shows the usefulness of the HGAs, specially HGA2 and HGA4. Looking at the overall results on the symmetric instances, one can conclude that the HGA4 is the best one and HGA2 is the second best one.

From the experiment we can say that HGAs have very good improvements in the solution over SGA for the TSPLIB symmetric instances. HGA4 is found to be the best and SGA is the worst. Now, to verify whether average solutions obtained by HGA4 is significantly and statistically different from the average solutions obtained by other HGAs, Student's t-test is conducted, and the results are provided in Table VI.

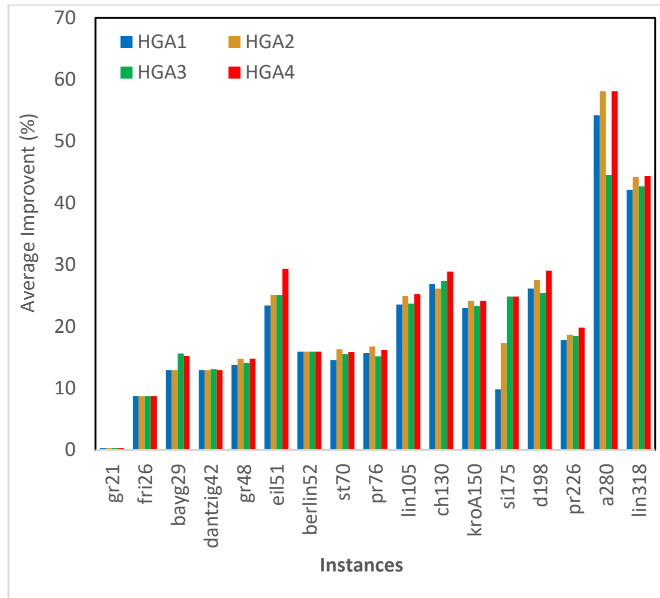


Fig. 7. Average Improvement (%) of Solutions by different HGAs over SGA for Symmetric Instances.

TABLE VI. THE T-VALUES AGAINST HGA4 AND THE RESULT ABOUT HGAS THAT OBTAINED SIGNIFICANTLY BETTER SOLUTIONS FOR THE TSPLIB SYMMETRIC INSTANCES

Instance	HGA1	HGA2	HGA3	Instance	HGA1	HGA2	HGA3
gr21	---	---	---	lin105	-11.40	-2.32	-8.11
Better	---	---	---	Better	**HGA4**	**HGA4**	**HGA4**
fri21	---	---	---	ch130	-7.24	-9.58	-7.60
Better	---	---	---	Better	**HGA4**	**HGA4**	**HGA4**
bayg29	---	---	---	kroA150	-14.32	---	-5.23
Better	---	---	---	Better	**HGA4**	---	**HGA4**
dantzig42	-10.46	-10.46	1.31	si175	-11.37	-10.22	---
Better	**HGA4**	**HGA4**	---	Better	**HGA4**	**HGA4**	---
gr48	-4.71	1.29	-3.52	d198	-11.47	-6.33	-10.10
Better	**HGA4**	---	**HGA4**	Better	**HGA4**	**HGA4**	**HGA4**
eil51	-15.00	-14.22	-14.22	pr226	-21.73	-14.62	-16.83
Better	**HGA4**	**HGA4**	**HGA4**	Better	**HGA4**	**HGA4**	**HGA4**
berlin52	---	---	---	a280	-6.25	---	-44.45
Better	---	---	---	Better	**HGA4**	---	**HGA4**
st70	-2.47	0.86	-0.59	lin318	-11.60	-0.37	-5.37
Better	**HGA4**	---	---	Better	**HGA4**	---	**HGA4**
pr76	-1.56	2.48	-2.78				
Better	---	**HGA2**	**HGA4**				

Looking at the Table VI, on five instances, HGA4 and HGA1 have no statistical and significant differences, and on the other twelve instances HGA4 is better than HGA1. On nine instances there is no statistically significant difference between HGA4 and HGA2; on the instance pr76, HGA2 is better than HGA4; and on the remaining seven instances, HGA4 is better than HGA2. On seven instances there is no statistically significant difference between HGA4 and HGA3, and on remaining ten instances, HGA4 is better than HGA3. On all seventeen instances, HGA4 is found better than other HGAs.

From this experiment, we can say that HGA4 is the best algorithm for symmetric TSPLIB instances also. Hence, for all asymmetric and symmetric instances, HGA4 is the best algorithm. To decide the second best algorithm for both categories of instances, we performed Student's t-test between HGA2 and HGA3 and reported in Table VII. From the table, it is found that out of thirty four instances, on nineteen instances, HGA2 and HGA3 have no statistical and significant differences. On the other nine instances HGA2 is better than HGA3, and on six instances, HGA3 is better than HGA2. Hence, HGA2 is the second best and HGA3 is the third best.

We now compare our proposed HGA4 with a state-of-art algorithm, namely, multi-start iterated local search (MS-ILS(h_1+h_2)) [4] on some TSPLIB symmetric instances of sizes from 21 to 318. We record best solution (BS), worst solution (WS), average solution (AS), and computational time (Time) (in seconds) for each problem instance in Table VIII. Better solutions are shown in boldfaces.

Looking at the average solutions, for the four instances, namely, dantzig42, gr48, lin105 and lin318 our HGA4 could find better solutions than solutions found by MS-ILS(h_1+h_2). For another two instances, namely, st70 and pr226, solutions by MS-ILS(h_1+h_2) are better. For the remaining instances, solutions are same. Of course, MS-ILS(h_1+h_2) takes less computational time. Overall, looking at the solution quality, our suggested HGA4 is found to be better.

TABLE VII. THE T-VALUES OF HGA2 AGAINST HGA3 AND THE RESULT ABOUT HGAS THAT OBTAINED SIGNIFICANTLY BETTER SOLUTIONS FOR THE TSPLIB ASYMMETRIC AND SYMMETRIC INSTANCES

Instance	HGA2	Instance	HGA2	Instance	HGA2	Instance	HGA2
ftv33	---	ftv35	---	ftv38	-0.29	p43	---
Better	---	Better	---	Better	----	Better	---
ftv44	-0.36	ftv47	-1.40	ry48p	-0.59	ft53	3.28
Better	---	Better	---	Better	---	Better	**HGA2**
ftv55	-2.40	ftv64	0.00	ft70	-1.59	ftv70	-1.22
Better	**HGA3**	Better	---	Better	---	Better	---
kro124p	---	ftv170	-4.98	rbg323	-4.83	rbg358	0.00
Better	---	Better	**HGA3**	Better	**HGA3**	Better	---
rbg403	-0.95	gr21	---	fri21	---	bayg29	---
Better	---	Better	---	Better	---	Better	---
dantzig42	-11.13	gr48	3.62	eil51	0.00	berlin52	---
Better	**HGA3**	Better	**HGA2**	Better	---	Better	---
st70	1.38	pr76	4.37	lin105	7.12	ch130	-3.42
Better	---	Better	**HGA2**	Better	**HGA2**	Better	**HGA3**
kroA150	5.23	si175	-10.22	d198	4.77	pr226	4.37
Better	**HGA2**	Better	**HGA3**	Better	**HGA2**	Better	**HGA2**
a280	44.45	lin318	5.33				
Better	**HGA2**	Better	**HGA2**				

TABLE VIII. THE T-VALUES AGAINST HGA4 AND THE RESULT ABOUT HGAS THAT OBTAINED SIGNIFICANTLY BETTER SOLUTIONS FOR THE TSPLIB SYMMETRIC INSTANCES

Instance	n	MS-ILS(h_1+h_2)					HGA4			
		BS	WS	AS	Time		BS	WS	AS	Time
gr21	21	370	370	370.00	0.06		370	370	370.00	0.00
fri26	26	102	102	102.00	0.09		102	102	102.00	0.05
bayg29	29	189	189	189.00	0.11		189	189	189.00	0.07
dantzig42	42	73	71	72.60	0.21		73	72	**72.80**	1.07
gr48	48	558	545	555.40	0.29		558	557	**557.90**	1.47
eil51	51	39	39	39.00	0.31		39	39	39.00	1.55
berlin52	52	541	541	541.00	0.32		541	541	541.00	1.80
st70	70	63	63	**63.00**	0.54		63	62	62.25	2.09
pr76	76	9214	9214	**9214.00**	0.70		9214	9069	9126.15	2. 62
lin105	105	1474	1460	1467.50	1.28		1474	1462	**1469.65**	3.98
ch130	130	458	458	458.00	1.99		458	458	458.00	4.20
kroA150	150	2153	2153	2153.00	2.37		2153	2153	2153.00	4.89
si175	175	304	304	304.00	3.05		304	304	304.00	8.54
d198	198	738	738	738.00	3.92		738	738	738.00	8.77
pr226	226	9360	9360	9360.0	5.05		9360	9350	9360.00	10.75
a280	280	148	148	148.00	7.36		148	148	148.00	13.10
lin318	318	2387	2381	2385.70	12.45		2395	2385	**2388.10**	15.24

V. Conclusion and Discussion

In this paper, a simple GA (SGA) and four hybrid GAs (HGA1, HGA2, HGA3 and HGA4) have been proposed for solving the MSTSP. The SGA used initial population by a sequential sampling, a proportionate selection, sequential constructive crossover, and adaptive mutation. Three local search procedures based on inversion, insertion and swap mutations, and a perturbation procedure have been used in different HGAs. The usefulness of the HGAs have been examined amongst themselves and calculated percentage of improvement of the obtained solution over the solution by SGA for the asymmetric and symmetric TSPLIB problem instances. The results show a very good improvement of the solutions by HGAs over the solutions by SGA. Further, it is seen that for asymmetric instances, HGA3 is placed in 2^{nd} position and HGA4 is the best one. For symmetric instances, HGA2 is placed in 2^{nd} position and HGA4 is the best one. Overall, for both categories of the instances, HGA4 is the best one, HGA2 is the second best and HGA3 is the 3^{rd} best. Further, a comparative study is carried out between HGA4 and by multi-start iterated local search (MS-ILS(h1+h2)). Looking at the solution quality, our suggested HGA4 is found to be better.

Though our proposed HGAs obtained very efficient solutions with slight differences between best solutions and average solutions, however, we admit that still there is an opportunity to improve the solutions by combining better local search procedures, another heuristic method and perturbation procedure to the instances that is under our study.

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Knowledge Extraction and Data Visualization: A Proposed Framework for Secure Decision Making using Data Mining

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***Abstract*—The decision-making process, promptly on time, is a crucial success factor in large organizations. Generally, the data warehouses of these organizations grow rapidly with the data generated from various business activities. This huge volume of data needs to be analyzed and decisions must be made quickly to meet the market challenges. Accurate knowledge extraction and its visualization from big data can guide decision-makers to conduct key analysis and make correct predictions. This paper proposes a decision-making framework that not only takes into account knowledge extraction and visualization but also considers the security of the data. The proposed framework uses data mining techniques to extract useful patterns, then, visualizes those patterns for further analysis and decision making. The significance of the proposed framework lies in the mechanism through which it protects the data from intruders. The data is first processed and then stored in an encrypted format on the cloud. When the data is needed for analysis and decision making, a temporary copy of the data is first decrypted, and then important patterns are visualized. The proposed framework will assist managers and other decision-makers to analyze and visualize the data in real-time with an enhanced security mechanism.**

Keywords—Big data; data mining; data visualization; classification; cloud computing; security

I. Introduction

Digital transformation has impacted many aspects of everyday life. Advancements in technology have resulted in an overall transformation in many industries changing the traditional ways of performing and managing tasks. As a result, the volume of available data has increased tremendously, which led to what is known as the era of big data [1] and [2]. Nowadays, organizations have the advantage of being equipped with large subsets of data that could potentially provide them with a competitive advantage. This is made possible by extracting insightful information that could aid organizations in decision making [2].

However, big data includes a mixture of structured and unstructured data that is diverse in nature and collected from many different sources such as smart devices, IoT sensors, social media applications, websites, emails, medical records and different types of documents [3] and [4]. Therefore, the data collected in its many forms does not directly help organizations. These large unstructured datasets need to be analyzed using specific methods such as data mining, machine learning, and artificial neural networks [5]. Once this is achieved, only then can big data serve as a driving force for organizations and provide value with advantages in many ways. These advantages include discovering trends and hidden patterns that could serve as a foundation for making future decisions in different aspects such as resource allocation, guiding production, and exploiting new opportunities [1] and [6].

The main contribution of this paper is to introduce novelty in classifying big data for decision making. The paper provides a proposed framework that helps organizations to make decisions based on information derived from classifying raw unstructured data using data mining algorithms. This information is then visualized in appropriate ways to present the extracted information in the best possible manner to enable managers to make informed decisions. Furthermore, a security mechanism is provided to ensure a high-level of security and protection while extracting rich insights of the data. Though, encrypting the data prior to storing in the database consumes additional resources, it is highly beneficial to the reliability of the data.

The remaining of this paper is organized as follows: Section II provides previous work found in the literature relating to big data and data mining. Subsequently, Section III explains the proposed framework while Section IV provides details regarding the experimental work. This is followed by Section V that discusses the results and findings of this research. Finally, Section VI concludes the work and provides future directions.

II. Related Work

While it remains ambiguous on what constitutes big data, there resides a consensus on at least three dimensions that prevail in the literature; volume, variety and velocity [7]. In brief, volume refers to the size of the dataset; variety refers to the different forms and sources of data that construct the dataset; and velocity refers to the speed of data generation and analysis [5], [7], and [8].

The concept of big data forced organizations to revolutionize the way they manage their data. Rather than just focusing on adopting effective methods to collect and store data, the challenge has shifted to finding effective mechanisms to extract valuable knowledge from this data. It also provides them with gaining meaningful insights that were hidden otherwise, which in turn offers many valuable opportunities. In doing so, organizations have the potential of gaining a competitive advantage over their competitors [6].

However, with all the benefits that could be achieved from big data, several challenges are imposed. Having large amounts of data makes it more difficult for organizations to extract valuable information [5]. Datasets are derived from many different sources such as databases, social media applications, emails, videos, documents, and IoT devices. In addition, the nature of these datasets is different where some could be structured, semi-structured or unstructured [9]. Therefore, traditional methods of analyzing data which organizations have been using are no longer effective in handling the large volume and diversity of data residing in large datasets [2]. Hence, new methods have been introduced to deal with the complex task of analyzing big data such as data mining, machine learning and artificial neural networks [5].

Data mining can be defined as the systematic process of extracting useful knowledge by examining large datasets from different sources and discovering hidden patterns. The knowledge that is discovered as a result of data mining provides valuable insights and aids organizations in decision making [10]. Data mining algorithms can be classified into two categories: descriptive models and predictive models. Descriptive models, referred to as unsupervised learning, are used to search for different patterns in the dataset and recognize any associations between them after applying revision techniques. In contrast, predictive models, referred to as supervised learning, are mostly used to predict and forecast outcomes from present behavior [11] and [12].

There are also different data mining techniques for analyzing descriptive and predictive models such as clustering, association mining, and classification. Clustering is the process of classifying similar objects into the same cluster depending on the specific characteristics of different objects in the dataset. Subsequently, the objects are grouped into different classes. By doing so, different inherent relationships become apparent, which provide valuable information that assists managers in decision making [13]. Alternatively, association mining involves discovering relationships between two items or concepts by first identifying the frequent itemset and then generating rules for them [14].

Moreover, classification in data mining techniques consists of two important phases namely, training and testing [11]. The training phase is concerned with building the classification model based on collecting training data in order to generate and create the classification rules. Subsequently, during the testing phase, the classification model is tested by applying classification rules and the accuracy of the result is determined by evaluating the true results of the classification rules [11]. Classification can also be categorized as supervised or unsupervised depending on whether the objects or cases are known in advance or not [10].

Many different classification algorithms can be used to analyze big data such as K-Nearest Neighbor, Naïve Bayes, Support Vector Machines (SVM), and Decision Tree [15] and [10]. K-Nearest Neighbor is a non-parametric simple classification method that is based on distance measurement. The algorithm classifies and stores any new cases depending on the distance function [15]. Alternatively, Naïve Bayesian algorithm is a probabilistic classifier, which deals with classification problems as probabilistic problems [16]. It fits very well with text data and requires a small amount of training data. However, the output or probability value should be assessed to ensure a high level of accuracy. Another example of a well-known classification algorithm is SVM where training data is represented as points in space separated into categories. Subsequently, new data is mapped to space, which belongs to such a category in that space. It is a memory-efficient algorithm suitable for high dimensional spaces and has the benefit of having a fast computational process [17] and [18].

In addition, the Decision Tree algorithm is also considered to be a widely used classification algorithm. It classifies data by generating a sequence of rules after assigning attributes to the data together with its classes. This algorithm is simple and easy to implement since it requires less data preparation and can work with numerical and categorical data. However, generating complex trees could be an issue. Moreover, it could be unsuitable where small variations exist in the data, which might result in a completely different tree [19]. In the current paper, Naïve Bayesian algorithm is used due to its fast and high scalability characteristic for the classification process.

As stated earlier, big data analysis provides many benefits and valuable opportunities for organizations with huge amounts of data [6]. These large complex datasets need to be normalized and analyzed in order to produce insightful knowledge for the organization to make important decisions and predictions for future situations [5]. Therefore, organizations and decision-makers need to exploit the data that is being generated and collected on a daily basis by analyzing it thoroughly. This will help them make informed decisions to run their business operations efficiently [20].

For this purpose, the concept of big data has become one of the important topics that organizations should invest in. This is because it provides effective ways of creating insights and knowledge from large amounts of unstructured raw data that would neither be obvious nor understandable unless some form of analysis is performed [20]. However, organizations and decision-makers first need to identify the data that has possible benefits. They also need to consider and prioritize their business needs and subsequently initiate the process of data collection and analysis. This is to reduce wasting valuable time in collecting and analyzing irrelevant data that will not lead to generating insightful knowledge [9].

The literature on big data analysis covers a wide spectrum of studies that have used classification algorithms for decision making in different fields [21], [22], [23], and [24]. In their study [21], they reported the successful use of Naïve Bayesian algorithm to classify and evaluate relevant alternatives for decision making in human-machine systems of critical applications. They indicated that although Naïve Bayesian is a simple classifier, trials have revealed that it is as effective as other complicated algorithms. In addition, the authors in [22] also used different classification algorithms to classify and predict solutions to help in making decisions with regards to heart diseases in patients. This helped the organization gain a competitive advantage as practitioners were able to make faster decisions based on the output of the algorithms.

However, these studies did not consider security measures. When unstructured data gets classified and structured to inform decisions, this poses security concerns that organizations need to consider. As mentioned earlier, the volume and type of data being created in recent times are much greater than before. Different types of data are being generated through different types of applications such as smart devices, IoT sensors, social media applications, websites, emails, and different types of documents [1]. Therefore, traditional security and privacy mechanisms used by organizations to protect their data are not fully capable of providing the same level of protection to big data as it holds different types of characteristics [3].

In [25], the authors reported that traditional security mechanisms such as access control, encryption, authorization, and multi-factor authentication are not considered to be effective methods for providing a protective environment for big data. Securing the network used for big data access, transformation, and storage is an essential part to prevent different types of intrusions and attack activities such as DoS attacks, unauthorized access, spoofing and spamming [25]. Credibility, availability, data privacy, confidentiality, authentication and integrity are a few of the security and privacy issues associated with big data [3], [4], and [26]. For instance, the authors in [27] proposed a 3D security model for big data that is based on user roles, data processes as well as security requirements. According to the authors, these requirements define the security objectives and goals that should be achieved to preserve data security and privacy.

Visualizing the patterns and output results of data mining could provide a comprehensive overview of the results of any process. This helps in understanding and providing insightful discovery since the data is presented in an attractive manner. Moreover, when knowledge or patterns are visualized, finding the relationship amongst data that is tested becomes an easier task than presenting it as normal data without any visual means. This is because the amount of tested data is enormous in big data and visualizing it in an attractive and understandable manner is essential for decision making [28]. In [29], the authors described several techniques that need to be considered in order to create meaningful visual data. They stated that data size and structure play a major role.

However, the visualization process might face some challenges. The authors in [30] stated that visualization tools should be able to provide an interactive output with minimum latency to meet or achieve user satisfaction. There are some techniques discussed in the literature that could be used to reduce the latency issue such as pre-computed data, parallelization for the processed and rendered data, and applying predictive middleware [31]. All these techniques could be used to reduce latency and avoid such drawback.

Visualization tools should be able to deal with and process semi-structured and unstructured data as most of the big data is in such a format [3]. Moreover, visualization tools should be capable of optimizing the performance in terms of scalability, functionality, and response time. Another challenge that could be faced with regards to visualization is information loss in order to scale the size of data for better performance which leads to data loss. In addition, the noise of visualization is a challenge because of irrelevant data or elements in the dataset. Generally, there is a need for high-performance tools to meet and achieve the desirable scalability, functionality, and response time [30].

III. Proposed Framework

In this section, we present the details of our proposed framework.

A. System Overview and Main Components

The system overview design describes the broad view of the system where such design is expressed by three major components that include the organizations, the cloud, and the decision-makers. The organizations generate the data, the cloud offers processing facilities, and the decision-makers have authoritative access to the processed data.

Several components formulate the framework presented in the above figure (Fig. 1) which are:

- The organization where the data is generated.
- Managers or decision-makers who access the cloud to retrieve the discovered knowledge.
- The database where all the generated data is stored.
- The classifier that categorizes the stored data.
- The processor that further processes the classified data.
- The pattern where the classified data relationship is discovered.
- The visualization process where the data becomes readable by managers and decision-makers.

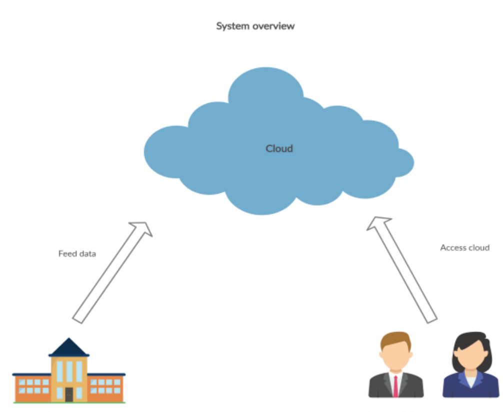

Fig. 1. Framework Overview.

B. System Flows

The organization creates and sends the data to the cloud through the web application that interacts with the cloud. The sent data is stored in a database that is located within the cloud. The stored data is then passed through a classifier that categorizes the data, which is then processed by the mining algorithm to generate insights or knowledge from such data. Subsequently, the produced result is visualized by visualization techniques which helps decision-makers take the right actions based on the knowledge that is produced. Managers and decision-makers access the cloud to retrieve the results using a web browser, which allows them to use a web application for granting access to the cloud. Fig. 2 illustrates the system flows graphically.

C. Security Mechanism

The system should implement security methods that protect and prevent data from breaches. According to the proposed framework, the data is first encrypted by the data owner or sender before storing it on the cloud where the data will be processed and stored in its encrypted form. A secure key is then sent to the receiver through a secure channel other than the cloud. Subsequently, the receiver accesses the cloud and fetches the encrypted data in an encrypted form, which is decrypted with a secure token. Fig. 3 shows the proposed security method.

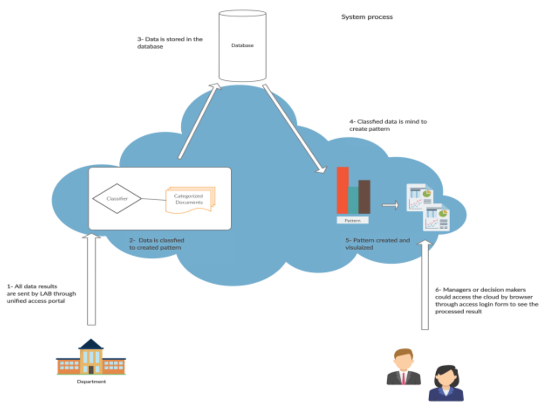

Fig. 2. Framework Process.

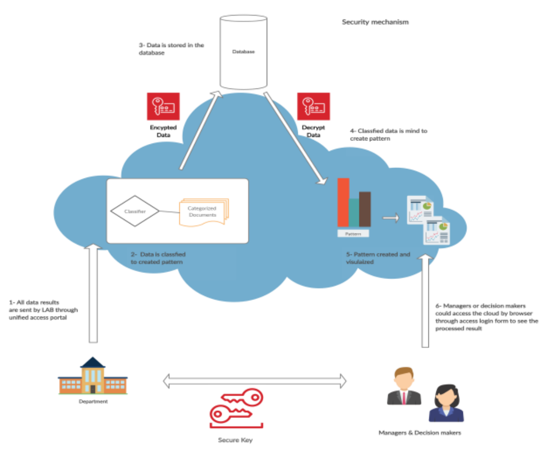

Fig. 3. Security Mechanism.

IV. Experimental Work

This section details the steps followed in performing the experiment which includes the setup and how the data is classified and how it is visualized.

A. Experiment Setup

Localhost for Apache server and MySQL database server were used during the implementation process with XAMMP software which offers all the necessary services for this experiment. In addition, a web application has been developed using ASP.NET and PHP to execute the functionality needed for the proposed framework. This includes processes for categorization, visualization, as well as data storage management. PHP was selected due to the fact it is supported by a range of libraries, functions, and modules that make the development of PHP based web applications swifter without any complications [32]. Similarly, ASP.NET is an open-source server-side programming language that is introduced by Microsoft to facilitate the development of dynamic web pages.

B. Classifier

The classifier functionality is based on organizing unrelated raw data into a categorized form that is based on predefined rules. In this work, we have utilized Naïve Bayesian classifier due to its speed and scalability features. The Naïve Bayesian classifier is based on Bayes' theorem. It assumes that each feature of a class is highly independent where the appearance of such feature in a specific class or category is not associated with any of the other features [33]. The classification process is achieved through the earlier probability and likelihood of a sample to a class. For this experiment, the classifier is built and trained using the above-mentioned web application to calculate the probability of each category.

C. Visualization

In practice, data visualization is used to convert plaintext data into figures and graphs that make such data more understandable for the managers and decision-makers. It provides a clear and comprehensive overview of the data in an attractive and interesting manner. In this work, Google Charts (Tableau) was used due to its capability of producing impactful and easy to read visual reports. Additionally, it allows the creation of customized dashboards based on the user's needs and provides the option of integrating them into the above-mentioned web application.

V. Result and Discussion

For this paper, data from a petroleum testing lab has been used and categorized into three classes based on the type of request from various customers. Those requests were grouped into three categories which are: critical requests (High priority), important requests (Mid priority), and normal requests (Low priority). As mentioned above, the Naïve Bayes classifier has been trained on the existing data which calculates the probability percentages of the submitted requests.

Based on predefined data and labels which are the three categories, the classifier has the ability to classify the submitted requests. For instance, keywords such as “urgently needed”, “quick action”, and “less than 8 hours” are categorized as High. In addition, keywords such as “diesel key test” and “quality check" are categorized as Mid, whereas keywords such as "more than 8 hours" and "storage facility" are categorized as Low. A condition was built on the body text of the request. If the request's body text percentage for High is greater than the body text percentage for Mid, the request will be categorized as "High". Alternatively, if the request's body text percentage for Mid is greater than the body text percentage for High or Low, the request will be categorized as "Mid". The default value is set to be "Low", therefore if the first two conditions were not met, the request will be categorized as "Low".

The categorized request is submitted to the database for visualization to assist decision-makers and managers. This categorization and visualization process provides an overview and explanation about requests fulfilment and the number of submitted requests.

The data is stored in an encrypted format using the AES algorithm with a 256-bit key that is difficult to break. Once the data is needed to be visualized, a temporary copy from the database is decrypted in order to extract knowledge and identify the important patterns available through a visual format. After the completion of this task, the temporary copy is discarded and only the obtained results are processed further. As a result of the visualization process, several graphs have been generated to fulfil the information needs of different customers. The following graphs illustrate the dataset that was used which includes 89 samples. The classifier gave the following results: high-priority requests (9), mid-priority requests (55), and low-priority requests (25). Fig. 4 and 5 present the visualization of these samples based on the day of one week, types of customers, and type of sample.

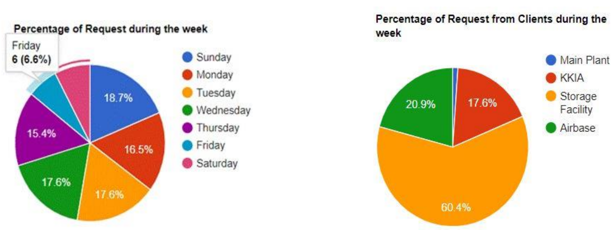

Fig. 4. Percentage of Requests during the Week and Percentage of Requests from Clients.

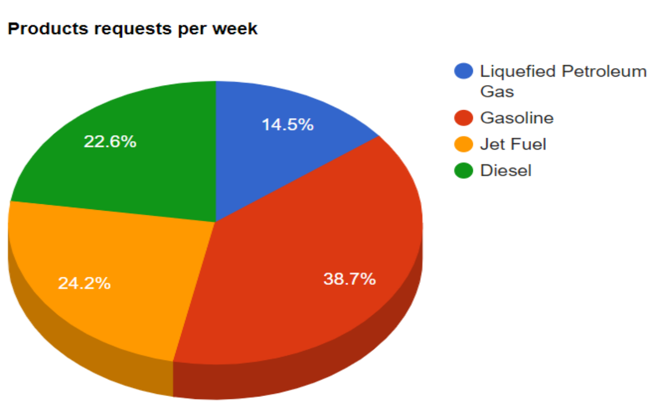

Fig. 5. Percentage of Product Types per Week.

Different types of tests could be performed in the lab based on customer's needs and each type has a specific duration requirement. Some tests could be performed in less than 8 hours, whereas other tests may take longer. For instance, the key test type could be identified in less than 8 hours whereas a full certificate test requires more than 8 hours. In all cases, the determination of the test duration is predefined by the lab unit. Fig. 6 shows the number of key tests and full certificate tests that have been requested during a week.

Additionally, the capacity of the lab in fulfilling the number of requests depends upon the number of employees available on that day. Fig. 7 shows the number of employees and the number of requests for each day of the week. This will help in balancing the workload among employees and avoids accepting any requests that cannot be fulfilled. Once the day is highlighted in red, this indicates the number of requests reached the maximum number of available employees. Thus, any subsequent requests will be denied for that day.

With regards to data security, data is stored in an encrypted format using the AES algorithm with a 256-bit encryption key. In this way, the data is protected against any malicious attacks that may affect the integrity and confidentiality of the stored data. Fig. 8 shows the encrypted data stored in the database.

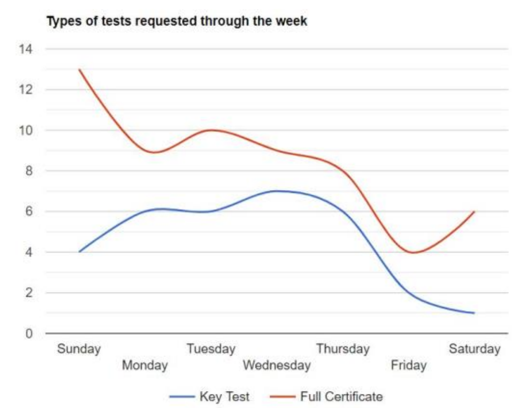

Fig. 6. Number of Requests for each Type of Test.

Indicating request numbers and employee numbers during the week

	Day	Number of Employees	Number of Requests
1	Sunday	15	17
2	Monday	15	15
3	Tuesday	15	16
4	Wednesday	15	16
5	Thursday	15	14
6	Friday	5	6
7	Saturday	7	7

New request can be handled · Requests near overcapacity · Requests overcapacity

Fig. 7. Employees and Requests.

Fig. 8. Encrypted Data.

VI. Conclusion and Future Work

Storing, analyzing and the visualization of big data are challenging tasks for any organization around the world. The data generated due to routine activities of an organization leads to an avalanche of raw and unstructured data. Data mining techniques can be used effectively to extract intrinsic patterns from data in the data warehouse and present them in an organized manner to assist managers and decision-makers to set future directions.

The proposed framework is capable of prioritizing requests received from customers with data visualization charts that allow decision-makers to optimize the available resources and produce the laboratory results according to the importance of the requests. The data visualization process can help decision-makers to either stop, increase, or decrease the working hours of laboratory staff for fulfilling various tasks. Furthermore, the proposed framework offers features that visualize the stored data without risking its security. This enables decision-makers and managers to monitor and track all the processes from request generation to the final fulfilment. Many business processes can be improved by identifying important patterns in the data that will lead to enhanced services. The proposed framework can be further enhanced by improving the quality of the classification process by taking into account more features of the input data. Further, the additional time consumed by the encryption technique will also be considered in our future endeavor. Additionally, the proposed framework will be equipped with a greater number of charts to assist decision-makers to visualize the data from different perspectives.

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Automated Labeling of Hyperspectral Images for Oil Spills Classification

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***Abstract*—The constant increase in oil demand caused a huge loss in the form of oil spills during the process of exporting the product, which leads to an increase in pollution, especially in the marine environment. This research assists in providing a solution for this problem through modern technology by detecting oil spills using satellite imagery, more specifically hyperspectral images (HSI). The obtained dataset from the AVIRIS satellite is considered raw data, which leads to the availability of a vast amount of unlabeled data. This was one of the main reasons to propose a method to classify the HSI by automatically labeling the raw data first through unsupervised K-means clustering. The automatically labeled HSI is used to train various classifiers, that are Support Vector Machine (SVM), Random Forest (RF), and K-nearest neighbor (K-NN), to accomplish the optimal accuracy to be comparable with another research accuracy. In addition, the results of the first region of interest (ROI) indicate that the SVM with RBF kernel obtains 99.89% with principle component analysis (PCA) and 99.86% without the PCA, which revealed better accuracy than RF and the K-NN, while in the second ROI the RF obtained 99.9% with PCA and 99.91% without the PCA, better than K-NN and SVM. The region of interests selected lies within the Gulf of Mexico area. This area was selected based on the frequency of usage in previous research in detecting oil spills.**

Keywords—Oil spills; hyperspectral imagery; unlabeled data; k-means cluster; classification

I. Introduction

Within the last century, Crude oil became the most demanded mineral in the global industry as it supports more than 40% of the global energy needs [1]. Accordingly, the world had increased the exporting rate to obtain more oil despite the amount of lost oil during the exporting phase in the form of spills or wells discharges. Oil spills occur when a liquid petroleum hydrocarbon is released into the environment, which could lead to the leakage of 4.5 million tons of oil in the marine or ocean water [2]. Oil spill pollution can cause several natural disasters such as preventing the sufficient amount of sunlight to penetrate the ocean surface and reducing the dissolving level of oxygen, and increase the threat of extinction of different kinds of animals in the marine environment due to reproductive rate may be slow and long term recovery will last longer than usual [3] [4]. Not to mention its harm to plants life. The huge amount of this oil loss leads to significant economic decline.

Several source of data type have been used in order to assist in locating the oil spills such as hyperspectral images and multi-spectral images which are different types of remote sensing data. It's found that the hyperspectral images (HSI) "Represented in Fig. 1." are the most used as it includes one continuous spectrum which is used in measuring each pixel and provide the ability to distinguish different objects [5], mentioning that the standard is that the spectral resolution is given in nano meters (nm) or wave number and more than 100 bands in various intervals of 5-10 nm throughout the visible light to infrared spectrum are frequently present in its content. [6] [7]. The mentioned datatype ensures that certain minor but important features could be detected.

Not only obtaining the data was burdensome process, another challenge faced was of acquiring unlabelled data. After a lot of research, to locate the oil slicks using the hyperspectral images, the research performed several steps such as pre-processing, classifiers, and machine learning techniques. The mentioned steps are python-based code with the aid of ArcGIS software. The classifiers require labelled data to run. The labelled data comes with a tag, the absence of this tag results in getting unlabelled data. The tag is the less obvious bit and it only depends on the context of the problem in which the system try to solve, and normally the prediction of a feature is based on other features[9].

Supervised and unsupervised machine learning algorithms, have shown significant results in acquiring information from huge datasets. Supervised learning is an algorithm that generalizes information from known data with signal or labelled examples such that the algorithm can be tested by recognizing new data [10]. Unsupervised learning is the process of dividing data into groups using automated methods for unlabelled or categorized data. The absence of labelled data for the learning algorithm can sometimes be useful since it allows the program to search back for patterns that were not previously examined [11]. In case of presence of few amounts of labelled data semi-supervised learning is specified for this process. This technique [12] solves the problem of missing data by making use of large amount unlabelled data and the few labelled ones' to create better classification.

In this paper, our principle purpose is to classify the unlabelled hyperspectral data by proposing the K-means clustering algorithm then processing on it various classifiers. To summarise, the research's important points are divided into five categories that the researchers want to achieve:

1) Pre-processing the HSI on ArcGIS.
2) PCA is used to reduce dimensionality.
3) Labelling the HSI the unlabelled data by K-means clusters.
4) Classifying image using SVM, RF and k-NN.
5) Comparing the results with PCA and without PCA.

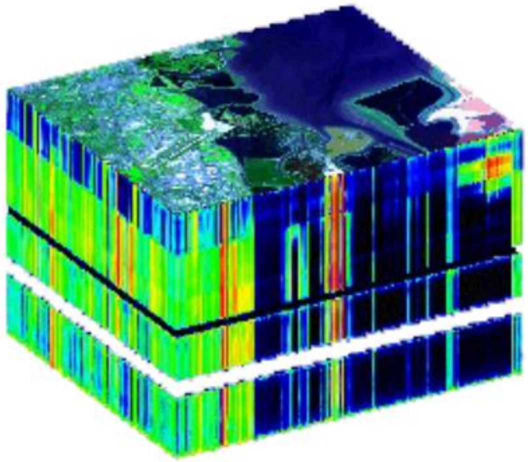

Fig. 1. Hyperspectral Image [8].

Techniques used in other areas of research are experimented in the field of HSI analysis. The main contribution of this paper following these objectives is utilizing the concept of applying k-means clustering with automatic selection of the most suitable number of clusters. The automated clusters are then used as a labelling technique within the field of oil spills detection using hyper-spectral imagery. This technique has been earlier used in [13]. The only other clustering for labelling technique used for oil spills was [6] by the C-DPMM clustering algorithm, which we followed by testing a different technique (K-means) to experiment its efficiency, especially it is considered a simpler technique.

Another contribution of the paper is presented the exact details about the experiment including the exact data and tools utilized, which has not been presented in such details in other publications.

The remainder of the paper is laid out as follows. Section2 gives a brief overview of related works that focuses on the task of classifying pixels into various oil types. Section 3 describes the dataset used in the system. In Section 4, it mentions our methodology by discussing extensively our mains steps in obtaining our main goal, which is classifying the HIS image. The results after that are presented in Section 5. Finally, in Section 6, conclusions are reached.

II. Related Work

Several systems focused on the task of classifying pixels into various oil types according to their spatial and spectral characteristics. Various techniques have been applied with numerous data types and structure. This section represents the most prominent work conducted in the fields related to the research at hand. In this section, it focuses on five main topics pertaining to this research. These topics cover a wide spectrum of research conducted within the areas of image processing and satellite imagery analysis. These topics are ordered as following:

- Labelling unlabelled data using k-means based clustering.
- Classification of HSI using SVM.
- Classification of HSI using DT.
- Classification of HSI using neural networks.
- Classification of HSI using neural networks.
- Usage of other classifiers.

A. Labelling using K-mean based Cluster

J. Xie and C. Wang [13] presented in their paper clustering as an unsupervised learning problem that uses unlabelled data to distinguish between groups of objects based on their features, which tries to group pixels with comparable spectral information into the same class. They collected a large number of synthetic random unlabelled datasets as part of the experiment. They experimented with various clustering techniques (presented in Table I), however they mainly focused on the k-means clustering algorithm as it doesn't need ground truth to initiate it. Then to minimize the number of clusters loaded by the k-means algorithm when searching the optimal number of clusters based on the k-d tree by extracting it from a plotted graph [14][15]. To classify the data they finally used the SVM to train the extracted new labelled data using several kernel functions. They compared the three methods which are (a) the fast global k-means clustering method, (b) the fast k-means clustering based on k-d trees, and (c) the global k-means clustering to choose the K-clusters. Following this, various kernels types are used to divide the data for the SVM, as shown in Table II. The results of the experiments on synthetically randomly created data sets show that the clustered SVM is very efficient and effective in categorizing completely unlabelled datasets. This inspired us to follow their methodology within our application domain.

TABLE I. CSVM Results [13]

Clustering Algorithm	Kernel Function	Classification Accuracy	Time
a	Linear Polynomial rbf	0.986 1 1	0.407 0.360 0.328
b	Linear Polynomial rbf	0.9836 1 1	0.265 0.203 0.172
c	Linear Polynomial rbf	0.9839 1 1	0.500 0.531 0.437

TABLE II. Results Presented in [21]

		Sensitivity	Specificity	Precision	Time (s)
SVM	RBF Linear Sigmoid	88.59 75.17 64.78	98.84 97.80 96.36	90.07 68.74 59.46	262.52 291.08 529.15
RF		93.83	99.32	95.35	269.33
DA	Linear Diag-Linear	78.92 65.46	78.92 65.46	96.84 94.16	8.12 3.5
KNN	K=1 K=3 k=5 k=7	91.97 88.41 86.98 86.40	99.01 98.61 98.46 98.39	91.75 89.51 88.75 88.62	3435.95 3521.30 3714.08 3886.08

B. Classifications using SVM Approach

Sahar A. and Ali H. [16] proposed a system that uses HSI images to detect oil spills. The collected user data is AVIRIS data of the Gulf of Mexico and the Adriatic Sea. They applied four various classifiers, which are SVM, BE, MD, and parallelepiped classifiers to classify the pixels. SVM, BE, MD indicated higher classification accuracy than the parallelepiped approach. Where BE, MD, parallel-piped, and SVM reached 88.4423%, 94.6399%, 46.9012%, and 99.8325%, respectively in the first dataset and reached 96.5338%, 98.6135%, 62.9116%, and 100% respectively in the second dataset. The system architecture also explained that there are some pre-processing steps before classifying as determining Region of Interest and applying PCA. They were able to identify the existence of various types of oils (i.e. dark and light oils). They also separated the appearance of pixels identified as oil from other pixels that identified as other components such as water.

Dabbiru, Lalitha, et al. [17] performed data fusion of hyperspectral and SAR imaging at both levels of data and functionality, to improve target detection, a combined spatial-spectral analysis is obtained and analysed the fused data to combine with Support Vector Machine (SVM). The ground truth classes are composed of six different classes. The system started with feature extraction of HSI and SAR, HSI using PCA to reduce dimensions, and SAR using GLCM to extract features from SAR data in different spatial orientations. The results of the SVM classifier were tested for each combination giving the highest accuracies for the two classes: healthy vegetation and lightly oiled vegetation. While the researchers were searching for the best accuracy classification approach the traditional approaches as SVM became of non-interest and they are still searching and developing new approaches in this field.

C. Classification using Decision Tree

Liu, Y. Li, P Chen and X. Zhu [18] proposed a system that used a Decision Tree (DT) to extract the information of oilspills based on minimum noise fraction (MNF) transformation.Before establishing the DT; the system used MNF to decreasethe redundant data and the noise of the image. The results forMNF-based decision tree classification can cluster the classesefficiently and distribute their accuracies. The study area ofthe system was the Gulf of Mexico which counted 69.16% ofthin oil film to approve as the dominant class, while very thinoil film, thick and medium thickness oil film counted 12.26%, 5.50%, and 6.22%, respectively.

D. Classification using Neural Network

JF Yang, JH Wan, Y Ma, and J Zhang [19] utilized a deep convolutional neural network (DCNN) for oil spill detection accuracy of the sea surface oil and comparing with the traditional SVM, RF, and DBN methods. Based on different-scale features, the results were briefed on the increase in the numbers of the accuracy of DCNN to reach 85%, which is even greater than SVM, RF, and DBN methods. While the results based on spectral feature information of one level WT with low-frequency component produced the highest accuracy detection that reached 87.51%. The author in [20] presented a spatial and spectral features by trying to stack auto-encoder (SSAE) to cluster and classify oil slicks on the surface of the sea and comparing it with the classical SVM, BPNN, and SAE. SSAE is based on the SAE network taking into consideration spatial information during classification. The accuracy results were impressive as the SAE and SSAE approaches have reached71.43% and 73.97%, respectively, while SVM and BPNN reached 68.89% and 63.81%, respectively. After comparing the images of SAE and SSAE approaches we may begin to understand that the SSAE eliminated the scatters across the thick film regions. Classification result accuracy increased by 4% to overcome the SAE over-fitting problem. We also compared the original image and PCA + SSAE and decision tree (DT), but SSAE accuracy was much better.

E. Classification using SVM, RF, DA and K-NN

In [21], comparison research of four supervised classifiers has been offered using HSI of different datasets obtained using AVIRIS sensor. They used the following classification methods which are SVM with different kernel types, Random Forest RF, Discriminant Analysis (DA) with two different kernels, and K-NN. They selected the more relevant bands from the utilized hyperspectral datasets using a mutual information-based filtering approach. The experimental results show that feature extraction as a pre-processing step of classification using mutual information is effective. Then, several measurements have been generated to evaluate each classifier overall accuracy. The demonstrative accuracy shown in Table II indicates that the SVM with RBF kernel performs well and appears to be the most effective as a supervised classifier for hyperspectral image classification, followed by RF and K-NN. The DA is the least excellent and performs badly in contrast to the other techniques.

In summary, it is viewed that most prominent techniques rely heavily on the availability of training sets, ether already available or gathered manually. The existence of labelled data in itself is considered an issue. Therefore this system focus on how to automate the labelling process while achieving an acceptable accuracy.

III. Dataset

Since it's concluded that the hyperspectral images are too expensive and time-consuming, the researchers figured to build their studies on very limited study areas as it is the most accurate for the detection of oil spill [16]. The hyperspectral image captures the area at a very large number of wavelengths and breaks the image down into tens of thousands of colours. AVIRIS remote sensing dataset which we are using is specialized in capturing the hyperspectral image, as it provides data of spatial and spectral features. This type of image is very large in size due to the huge information reflected from the ground features for each pixel in different wavelengths in bands. The visible RGB spectrum is used to determine the range of oil spills detected at each pixel, which ranges from 0.35 to 2.5 microns: In 224 bands, blue 0.4 microns, green 0.53 microns, and deep red 0.7 microns were used. The kind of oil thickness and the wavelength range of each band are significant characteristics of each band. Sample of the data is presented in Fig. 2.

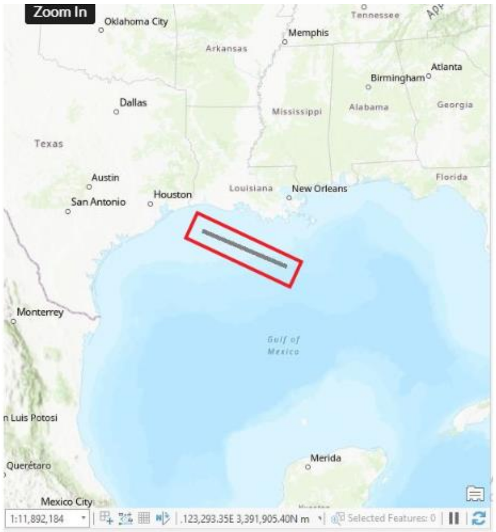

Fig. 2. Gulf of Mexico AVIRIS Flight Strip.

A. Region of Interest

As our area of interest is "Gulf Of Mexico", we obtained the data using an AVIRIS camera which collects the data using flights drawn on the map, so from the nearest flight record, a 9.2 GB dataset was collected for the mentioned location in binary [22]. The dataset contains two important files, which are the header file that contains information about the image, and the second file is the Bip file of the image. To prepare our data to import to our platform we used to convert our data from binary format into four files the most important one is TIFF (Tag Image File Format), which has four types one of them is RGB which we need while dealing with our hyperspectral /multispectral images.TIFF files own the privilege of the option of owning a supplementary file called TFW which contains six rows of data [23].

For this research, we have downloaded data for two different flights. The utilized flights are:

- Dataset 1 (name: f100523t01p00r08, Id: f100523t01, Flight: 100524).
- Dataset 2 (name: f100525t01p00r05, Id: f100525t01, Flight: 100525).

IV. Methodology

The proposed system is used to reduce the environmental disorders that are caused by oil spills, using hyperspectral remote sensing imagery. The obtained AVIRIS data is enhanced first using ArcGIS to be easily imported in python code. The extracted image is analysed by unsupervised classification to label the data by using a clustering algorithm which is implemented by python code. We used the labelled K-means image to be able to train our system with various classifiers and test its performance using the original enhanced image. Fig. 3 explains the steps of the system.

In the beginning, we worked on ArcGIS software [24] to prepare the AVIRIS dataset in order to efficiently reach our goal. Firstly, we imported the image in the ".bip" extension which in the geographic field, is one of three primary ways for encoding picture data for multiband raster images. Since the imported image is in binary format, which is a black HSI, we assigned the RGB of the whole image. Furthermore, we enhanced the image by using different methods as histogram equalization and percent-clip. At the end of the process, we took a clip after picking the ROI of the image and save it as a ".tif" extension to reduce its size [25]. These steps are presented in Fig. 4.

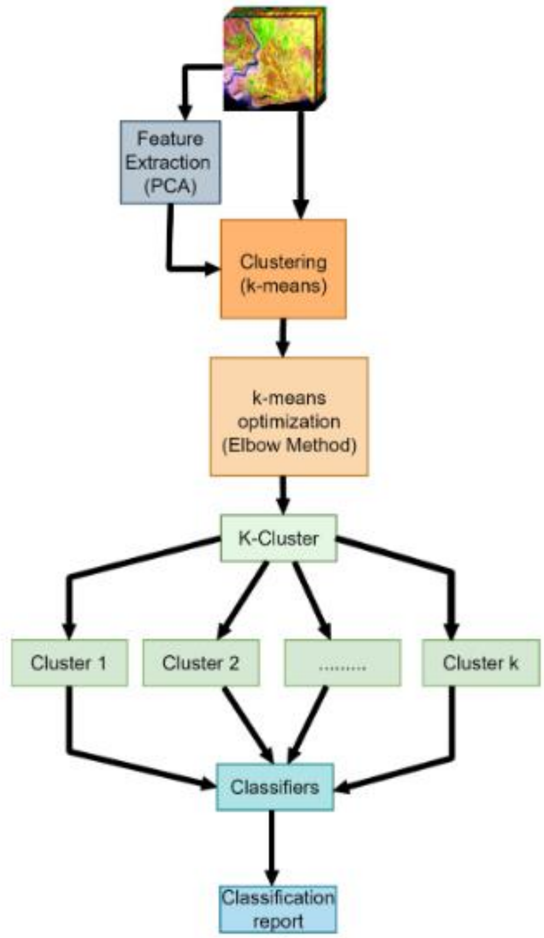

Fig. 3. Flow Chart.

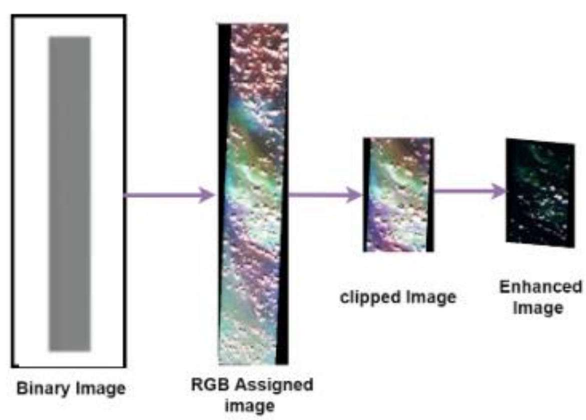

Fig. 4. ArcGIS Steps.

Initially, we extracted the features of the hyperspectral clipped image using PCA. Accordingly, reduce the redundant features. In order not to accidentally lose the image's features in this process, we compared the extracted classification results using PCA and without using PCA. The hyperspectral image is composed of three dimensions, we converted it from a 3D-cube image to 2D image preserving its important features in each band by the concatenation of (x, y) dimensions.

A. K-means Clustering

The second step is using the k-means unsupervised cluster for labelling our data. The output of the 2d array is taken as an input for the k-means cluster [26]. To determine the number of clusters, we optimized k-means by elbow method using mean and median methods as follows in equation 1, 2 and 3:

$$Odd_{ME} = \frac{X_{\frac{n}{2}} + X_{\frac{n}{2}}}{2} \tag{1}$$

$$Even_{ME} = \frac{X_{n+1}}{2} \tag{2}$$

$$Median_{ME} = \frac{MinVal + MaxVal}{2} \tag{3}$$

The unsupervised classification is considered an effective method for unlabelled data, K-means cluster was the optimal choice to be used as a labelling technique in pixel by pixel labelling. This technique separates the dataset into distinct groups based on how closely the data points are together, and these groups are referred to as “clusters”. Euclidean distances used to determine how close data points are to each other. To implement this technique, one data point is assigned per cluster, known as the “centroid”. Then, based on the cluster with the closest mean value, each point is assigned to it. After all of the points have been assigned to clusters, the means are calculated again, and the procedure is repeated until the mean square error of two consecutive processes is the same. The K-means cluster contains the input data into clusters that contain image features [27].

B. Classifications

The final step is the classification which is done by trainingdifferent ROI hyperspectral imagery, using three classifiers(SVM, K-NN, RF), and testing their performance.

1) Support vector machine classifier: The SVM tries toobtain the optimal hyper-planes between different points ofclasses by the selection of the largest gap between pointsand reducing the error using the optimal hyper-plane to avoidthe occurrence of over fitting. The different kernel functionsare used in different hyper-planes as well. The radial basis function in our system which is used according to [27]. The RBF kernel is considered the best among the Polynomial and Linear kernels, when it comes to classifying hyperspectral images, due to the high number of layers within the image. Polynomial and Linear kernels appeared to be time-consumingand low efficiency while using hyperspectral images.

2) K-Nearest Neighbour:k-NN approach in particular, usesnearest neighbor (NN) classifiers which are one of the mostbasic and yet effective classification criteria, and they areextensively utilized in practice. This approach is consideredsupervised neural network classification. A training set ofpattern vectors from such a class is provided for each class asa set of sample models. When classifying an unknown vector,its k nearest neighbors are discovered among all prototypevectors, and the class label is determined using a majority rule.The value of k should be odd to avoid conflicts on class overlapregions. Although this rule is basic and straightforward, it hasa low error rate in practice. For this study we estimated ModelEvaluation for k to 7.

3) Random forest: The random forest classifier is mainlycomposed of several tree classifiers, each one of the trees isgenerated using a random vector obtained independently fromthe input vector. Each tree gives a vote for the most convenientposition to classify. In our system we estimated the numberof trials in the RF by 100, applied the idea of grouping thesimilar features in classes, and used these classes as subsetswhich are chosen randomly to train the data.For all the classifiers, the training and testing methods areassigned to 67:33% respectively in order to reach differentaccuracies. We compared the results to adjust the best classi-fication method.

V. RESULT

In this study, the data preparation stage is feature extraction by labelling the data using a clustering algorithm. Two HSI from the “Gulf of Mexico” were used to validate the proposed method. The experimental results using the two datasets are summarized to be labelled by the k-mean clusters on HIS demonstrate that the SVM and RF techniques perform close and better accuracies done by the K-NN algorithm. To be able to train the classifiers using labelled data we use k-means cluster for that. Each image contains a different number of clusters used for the process according to the elbow method we discover that the optimal number of k to be able to label the data according to the extracted result. As shown in Fig. 5 and 6, the graphs represent the k value as in the first dataset it contains 6 k-clusters and the second dataset is 4k-clusters. The right figure represents the generating labelled data using the optimal clusters.

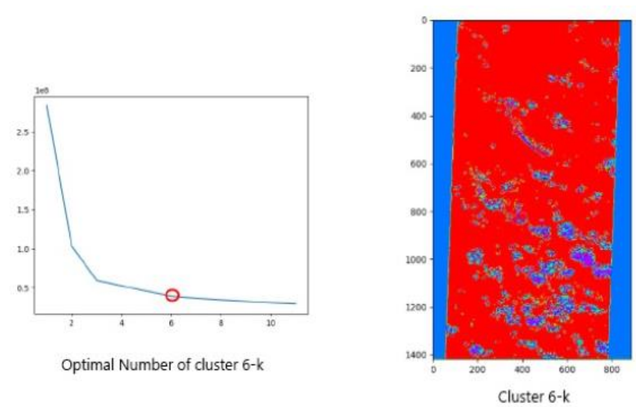

Fig. 5. Elbow Method applied to Dataset 1.

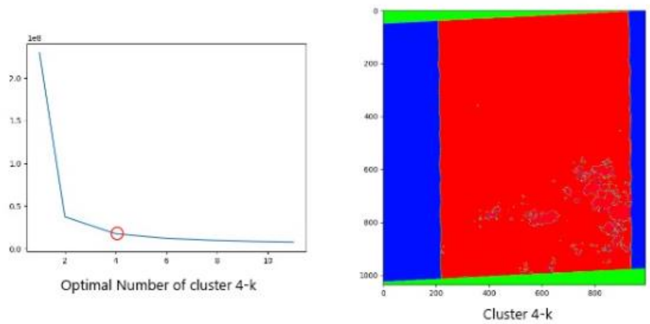

Fig. 6. Elbow Method applied to Dataset 2.

The obtained labelled data are classified with three different classifications, which are SVM, RF, and K-NN as mentioned before. In discovering the best way for the automated detection of oil spills a comparison is demonstrated between the results of the different classifiers. A confusion matrix is utilized to determine the accuracy of each classification. Table III and Table IV exhibit the confusion matrices for the first and the second datasets respectively. For the chosen dataset, it can be observed that the majority of classification algorithms work effectively and have an accuracy rate of more than 90% without the presence of overfitting, which was validated by comparing the output results from the training and testing accuracies over the two utilized datasets. It has been demonstrated that the SVM with the RBF kernel, RF, and K-NN achieved the best classification results for 67 selected pixels was training and 33 selected pixels as testing. The accuracy has been calculated by using ready-made python functional measurement criteria that are mainly used in similar systems:

$$Accuracy = \frac{(TP+TN)}{(TP+TN+FP+FN)} \tag{4}$$

1) First dataset results: The first dataset performance of SVM with RBF kernel and PCA was 99.89% and without PCA was 99.86%, then the RF classification results with the PCA was 99.78% and without the PCA was 99.85%, while the results for the K-NN with the PCA was 99.77% and without the PCA was 99.78%. After observing the classification results, it was concluded that the SVM has the highest accuracy results followed by the RF classification which is considered slightly better than the K-NN. The achieved results were close to what was mentioned in [21] as the SVM, RF, and K-NN classifiers were achieving the best accuracies respectively, which is the same conclusion that was reached in this dataset. 2) Second dataset results: The second dataset classification results are completely different from the first. The RF performed the best results with and without PCA to achieve99.90% and 99.91% respectively, then the K-NN performance was unexpected to be better than SVM and achieve high results as it reached 99.89% and 99.88% respectively with and without PCA, while the SVM which performed the best in the first dataset, performed the worst in the second dataset to attain 98.31% and 98.17% respectively with and without PCA. Classifiers' accuracy results are relatively close to each other with a slight difference between them, they performed unexpectedly in the two datasets. The SVM performed the best in the first dataset and the worst in the second dataset which determines that choosing the optimal hyperplane in the second dataset was not accurate. Furthermore, the three classifiers' accuracy before and after PCA are relatively similar. Although processing time without PCA is quite long. PCA was used to reduce the dimensionality of datasets before the classification procedure, and eventually enhance the runtime [16]. The difference in runtime is shown in Table V by specific platform of OS version(windows 10.0.19042) with Processor Intel(R) Core(TM) i5-10210U CPU @ 1.60GHz, 4 Core(s), 2112 Mhz, 8 Logical Processor(s). There is a lack of clarity in the comparative results with the similar systems since they did not mention the exact AVIRIS flight nor the source of the ground truth data. In conclusion, the SVM, K-NN, and RF techniques are accurate in classifying hyperspectral datasets from the Gulf of Mexico AVIRIS flights.

TABLE III. ACCURACY OF THE FIRST DATASET – GULF OF MEXICO

Classifier	With PCA	Without PCA
SVM	99.89%	99.86%
Randome Forest	99.78%	99.85%
K-NN	99.77%	99.78%

TABLE IV. ACCURACY OF THE SECOND DATASET – GULF OF MEXICO

Classifier	With PCA	Without PCA
SVM	98.31%	98.17%
Randome Forest	99.90%	99.91%
K-NN	99.89%	99.88%

TABLE V. CLASSIFICATION RUNTIME

	Classifier	Time Taken in Hours
Without PCA	SVM	10-12
	RF	5-8
	KNN	12-15
With PCA	SVM	10-11
	RF	2-3
	KNN	11-13

VI. CONCLUSION AND FUTURE WORK

The hyperspectral imagery typically generates a massive amount of data, which makes the computing expense and associated classification work might be challenging. The paper demonstrates several solutions and methods to efficiently and accurately detect oil spills. However, labelling the HSI is high expensive, and time-consuming the clustering technique by the-means was used for labelling our datasets. The k-mean labels were classified using supervised classifications to train and test the model according to the original HSI which performed high accuracies using the SVM, RF, and K-NN approaches. Futuristically, it is expected to test the system on various other datasets to ensure the generalization of the technique used. The hyperspectral imaging accuracies are commonly high, thus we can attempt using other clustering techniques that are expected to perform better than the k-means clustering due to its simplicity, to perform a more accurate and efficient system.

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Logistic Regression Modeling to Predict Sarcopenia Frailty among Aging Adults

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***Abstract*—Sarcopenia and frailty have been associated with low aging population capacities for exercise and high metabolic instability. To date, the current models merely support one classification with an accuracy of 83%. The models also reflect overfitting dataset complexities in predicting the accuracy and detecting the misclassifications of rare diseases. As multiple classifications led to incongruent data analyses and methods, each evaluation yielded inaccurate results regarding high prediction accuracy. This study intends to contribute to the current medical informatics literature by comparing the most optimal model to identify relevant patterns and parameters for prediction model development. The methods were duly assessed on a real dataset together with the classification model. Meanwhile, the obesity physical frailty (OPF) model was presented as a conceptual study model. A matrix of accuracy, classification, and feature selection was also utilized to compare the computer output and deep learning models against current counterparts. Essentially, the study findings predicted that an individuals' risk of sarcopenia corresponded to physical frailty. Each model was compared with an accuracy matrix to determine the best-fitting model. Resultantly, logistic regression produced the highest results with an accuracy rate of 97.69% compared to the other four study models.**

***Keywords*—Sarcopenia; frailty; logistic regression model; prediction**

I. Introduction

Obesity has been proven to induce frailty in elderly individuals through the most extensively utilized obesity measurement: body mass index (BMI) and age. High risks of coronary heart disease, stroke, and early death have been recently linked to obesity [1, 2] with the perpetually rising rates among aging adults: a drastic 56% increase among individuals between 60 and 69 years old and a 36% increase among individuals over 70 years old in 2020 compared to 2010 [3, 4]. Currently, 37% of adults over 65 years old are obese with a predicted rise in the future [5]. Both skeletal muscle and fat mass would decline between 60 and 70 years of age, thus resulting in a different body distribution [6, 7].

Frailty and obesity are connected to disabilities, high healthcare usage, institutionalization, and early mortality [11-18] with specific symptoms: self-reported tiredness (muscle weakness based on grip strength), slow walking pace (0.8m/s), and inadequate physical exercise [19]. Contrary to popular assumptions, obesity seemingly increased the risk of frailty [4]. According to the Cardiovascular Health Study [20] in Finland, frail patients reflected higher BMI than pre-frail or robust counterparts.

Obesity has posed significant intricacies for public health organizations worldwide. Specifically, the steady and global rise of obesity among aging adults is a substantial phenomenon in both developed and developing countries. Despite the current increase in lifespan, obesity among aging adults is parallelly rising with additional years of disease (cardiovascular illness) susceptibility. In this vein, aging obesity induces significant health complications and a high risk of cancer and death. As a significant contributor to insulin resistance and metabolic syndrome, aging is associated with high cholesterol levels. Knowledge of the primary causes of aging and age-related disorders proved necessary given the seriousness of aging obesity. This study aimed to correlate the fundamental causes of both obesity and aging to indicate that age-oriented changes in fat distribution and metabolism potentially intensified aging and the onset of age-related diseases. The primary elements in a vicious cycle [31] are listed as follows: BMI between 25 and 29,9 kg/m2 is categorized as overweight while BMI over > 30 kg/m2 is obese under the WHO BMI criterion. [32] Nevertheless, the BMI criterion (the most extensively utilized obesity index) overestimates and underestimates obesity in muscular people, including aging adults who have lost body weight. Obesity is also closely associated with other adverse health conditions, such as type II diabetes, heart disease, cancer, and even death [33].

The current "aging population" reflects a significant rise in the number and proportion of elderly people. Elderly individuals are among the most sedentary community members as aging implies the loss of bodily function and low capacities to sustain physical function and physical autonomy despite a longer lifespan. Consequently, most aging adults could be reduced to rudimentary physical skills that induced physical dependence. In this regard, low life quality and negative social and economic (healthcare) implications were gravely concerning [26].

Prediction models could be employed as a method to screen for physical frailty among older adults. In line with international authors, the aforementioned models denote an explicit and clinically relevant tool that facilitates the systematic utilization of routinely collected data and improves information quality and reliability [11]. This study aimed to forecast individuals with the risk of sarcopenia following a physical frailty prediction model for the oldest primary health patients in the community through participants' clinical variables.

The following sections in this article are organized as follows: Section II presents an overview of obesity and physical frailty with details on relevant works, Section III outlines the model method and materials, Section IV highlights the critical evaluation, Section V presents the experimentation and result evaluation, and Section VI concludes the study.

II. Problem Statement and Limitation

The rapidly aging global population implicitly affected economic growth and health care. In Malaysia, older age groups contribute to 10.3% of the total population based on the 2019 population projection. On the global scale Malaysian has the fourth-fastest aging nation with a 26% rise between 2008 and 2040 [24], the Malaysian population is anticipated to age by 2040 [20] The age structure was also assumed to change drastically following the paradigm shifts of decreased fertility and increased longevity.

The current circumstance poses a novel challenge to the public health care system due to high medical costs and expenditures. Following statistical evidence, the growing elderly population was primarily caused by a high dependency ratio. Although the increase was suggested as a contributing factor, statistics implied the rise to be a primary cause. [25].

Overfitting datasets significantly lowered prediction accuracy due to multiple classifications, thus causing incongruencies between the data findings and techniques employed [25]. Therefore, each evaluation reflected inaccurate results, low prediction accuracy, overfitting tendencies, and poor performance.

Prediction models that demonstrated imbalanced datasets were more commonly skewed against consensus definitions. The connotations were notably essential given the high costs of misclassifying minority examples, such as rare disease identification [22]. Regardless, the lack of available models hampered the management of obesity frailty and dataset complexity to foresee the obesity implications on public health. The limited parameters utilized to predict outcome accuracy inevitably affected specific dimensionalities [27].

A. Elderly Population Demographics

Regarding the rapidly aging global population, a significant increase in average life expectancy in the 20th century reflected one of the most notable social achievements. The rise resulted in a change of major disease and death factors or "epidemiological transition". The transition followed the decline in infectious and acute diseases and subsequent rise of chronic ailments. The data collected from various studies highlighted that recent life expectancy changes were correlated to high disability rates [28]. The Malaysian population would predictably increase from 32.5 million in 2019 to 32.7 million by 2020. In 2020, the population of individuals between 15 and 64 years old might decrease from 69.8% in 2019 [29]. The increasing number of obese senior citizens was linked to functional disabilities following muscle loss [30]. Based on the Malaysian Adult Nutrition Study, obesity rates have nearly doubled with an increase of overweight and obese adults by over 60% in the last decade. In 2016, 29.1% of individuals were found to be overweight while 14% were obese [31].

B. Aging Related Diseases

An increase in overweight (4.4%) and obesity (14.6%) cases was identified in Malaysia between 1996 and 2018 [32]. Specifically, obesity was found to be higher in women than men [32]. Adults from 40 to 59 years old reflected the highest rate, followed by Malays, Chinese, and the Aborigines [32]. To date, Malaysia is known as the fattest nation within the Southeast Asian region [33] following Fig. 1. In this vein, obesity poses crucial health, growth, and prosperity-related concerns in many countries, particularly Asian nations.

Recently, Malaysia was ranked the second-most overweight nation in East and Southeast Asia [34].

Inactivity also elevates the risk of heart disease and mortality [35]. As health behaviors, obesity, and chronic diseases relied on various biological mechanisms (glucose control and inflammation) [33], investigating the interrelationships between these factors could disclose disease mechanisms and facilitate clinical study designs.

In Table I, the comparative studies on initial accuracy models with various parameter types were utilized for obesity and frailty. DeGregory et al. [36] stated that obesity-related complexities and implications could be identified, recognized, and forecasted with machine-learning algorithms. Notably, the key component analysis (PCA) accuracy level was 83% (extremely high). Meanwhile, Bassam et al. [37] defined logistic regression with KNN and SVM for modeling. Resultantly, SVM demonstrated the highest accuracy level (73%) which involved specific attributes (age, BMI, gender, waist circumference, physical activity, diet, pre-existing hypertension, family history of hypertension, and diabetes) as modeling accuracy contributors.

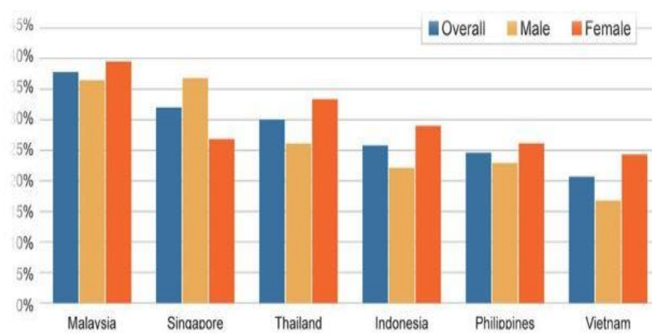

Fig. 1. OBESE Population with BMI >25.

TABLE I. COMPARATIVE STUDIES ON EARLY MODEL ACCURACY

Author	Model	Predictors used	AUC
DeGregory et al	Linear and logistic regression, artificial neural networks, deep learning, decision tree analysis, cluster analysis, principal component analysis (PCA), network science, and topological data analysis	Age, BMI, family history of diabetes, hypertensive status, family history of hypertension, sex, inactivity, and improper diet	83%
Bassam et al.	Logistic regression, k-nearest neighbor, KNN, and support vector machine (SVM)	Age, BMI, sex, waist circumference, physical activity, diet, pre-existing hypertension, family history of hypertension, and diabetes (type II)	SVM: 73 %
Jindal et al.	Random forest	Age, BMI, weight, and height	89.68
Seyla et al.	SVM	Age, BMI, BP, HDL, and LDL cholesterol A1C, and smoking	66.2%
Zheng et al.	Improved decision tree (IDT), KNN, and artificial neural network (ANN)	Inactivity, improper diet	KNN – 88.82% IDT – 80.23% ANN – 84.22%
Brandilyn et al.	Random forest model, and performed cross	Age, BMI, and physical activity	70%

Jindal et al. [38] deployed random forest using the attributes of age, BMI, weight, and height with 89.68% accuracy. Following Seyla et al. [38], the sample employed SVM with the attributes of age, BMI, BP, cholesterol, and smoking with 66.2% accuracy. Zheng et al. [39] elaborated on the decision tree, KNN, and ANN models with 88.82%, 80.23%, and 84.22% accuracy, respectively. Regarding inactivity and poor diet, Brandilyn et al. [40] assessed the random forest model using cross-sectional research based on age, BMI, and physical activity as the modeling parameters with 70% accuracy. The accuracy corresponding to the linear model categorization was merely 90.5%.

Limited feature and dimension selection were identified in driving the result plots under the curve. Carlos Rodriquez's model could not provide a clear depiction of attribute selection following the small number of respondents while other model limitations were primarily related to low model dependability. The model accuracy was also found to be low. Consequently, the approach proved unreliable following sample size insufficiency to support data-derived conclusions.

This study encountered several limitations. First, the model comparisons lacked obese individuals who reflected a higher frequency of pre-frailty and frailty in a 22-year follow-up study in Finland. As such, obesity could be a primary factor regarding frailty progression [21, 22]. As small sample sizes instigated overfitting following past studies, the samples complemented large datasets compared to data from a single-site experimental clinical trial. Regarding computing complexities, addressing the decision tree application with appropriate thresholds denoted the most intricate class of algorithms. Thus, deep learning algorithms were typically most effective on relatively large training datasets. Notwithstanding, dataset pre-processing and standardization could be time-consuming [8].

Another element potentially limiting the study validity was data collection. According to Jacy Aurelia, the cross-sectional study design deterred the causal relationships between clinical variables and study outcomes. The findings could not be generalized as the sample represented a specific community. Alternatively, longitudinal and multi-center studies should be performed to better understand the relationships and verify the transition between frailty levels based on case severity and reversibility in the medium and long terms [9].

The integration of both measures could elevate precision in identifying aging adults who were more vulnerable to adverse health events. For example, a conceptual development that involved scholarly collaboration from various disciplines could alleviate some of the aforementioned shortcomings. Notably, a hypothetical future model of frailty among elderly individuals should not be as restrictive as the physical phenotype or as broad as the index derived from multiple domains [10].

III. METHOD AND MATERIAL

This study aimed to determine the use of specific parameters and predict obesity and frailty with logistic regression. Primarily, the suggested methodology strived to develop the prediction categorization criteria for the most optimal model (Naïve Bayes, logistic regression, random forest, decision tree, or KNN). This section explained the proposed research methodology to compare the performance of all five study models and employ the most accurate predictive model with specific parameters.

A. Data Pre-processing

Data pre-processing is a critical stage in data management before being utilized in data-mining algorithms. The procedure encompasses several steps: cleaning, normalization, and feature selection transformation. Data transformation significantly influenced this study analysis as most of the features were categorical with a combination of string and special characters. The values needed to be converted into numeric-categorical values for improved prediction performance by the predictive models. The cleaned data would then be split into two sets (train and test sets) after data pre-processing. The ratio between both sets (80:20) proved ideal for data-splitting. Specifically, predictive model accuracy was higher if the model trained on 80% of the data and assessed the model performance on the remaining 20%. In model development, five supervised learning classification models were implemented for prediction. Supervised learning models were chosen in line with the target attributes for known outcome prediction. The data was fed into the predictive models while prediction accuracy was employed to assess the model performance post-test.

B. Feature Selection

As feature engineering involves the process of selecting a subset of relevant attributes for model inclusion, various cutoff points were established for the most influential traits to be incorporated into the tests. The accuracy of each algorithm was compared with a dataset using the selected features. The process was then repeated with multiple thresholds for optimal results.

C. Classification using Data Mining

Several algorithms could be run on a dataset to determine the most accurate counterpart in predicting obesity and frailty impacts. Clustering and association rule-mining denoted some of the tasks that could be accomplished through data-mining apart from classification and prediction. The data were assigned with a pre-defined class label using a two-step process for dataset classification. Specifically, training data were analyzed for classification model development (classification rules) that described a set of pre-defined classes. Meanwhile, the model was classified post-test data as part of the second phase to determine model accuracy.

Pseudocode: Identify Response and Explanatory Variables

1. Original Dataset ← contains all variables
2. Target ← Obese and Frail, Non-obese and Frail, Obese and Non-Frail, Pre-frailty
3. Response Variable ← Target
4. Correlation Matrix ← Generate a correlation plot to find highly correlated attributes
5. If Correlation => 0.50 THEN
    a. Explanatory Variable ← Feature == Chosen
6. Else
    b. Feature == Dropped
7. Data ← Explanatory Variable, Response Variable
8. Data.to_csv()
9. Logistic Regression : Input Test X, Target Y
10. Import Logistic Regression from Linear Model
11. LogisticRegr <– LogisticRegression ( )
12. If LogisticRegr.fit( ) == NULL Then
13. Return "Error"
14. Else LogisticRegr.fit (x_train, y_train)
15. Train the model on the data
16. Accuracy ← LogisticRegr.score (Test Data)
17. Return Accuracy
18. Confusion Matrix ← LogisticRegr.predict (Test Data)
19. Return Confusion Matrix
20. Combined Model : Input ← Features == LogisticRegr
21. If LogisticRegr.fit ( ) == TRUE Then
22. Create New Model OPF (Obesity Physical Frailty)
23. Else
24. Return.

The aforementioned logistic regression pseudocode indicated the steps to define the coded independent variables X and Y. A logistic regression package was subsequently imported from the "sklearn linear model" library. A logistic regression model with all the unspecified parameters (set to default) was generated as the third stage. Otherwise, the function progressed to the data training phase following step 7. A model would learn the relationship between "x train" and "y train" through split-data training. The model accuracy was then measured for performance assessment. The logistic regression function was scored for improved model accuracy. Lastly, a confusion matrix table described the classification model performance on a test dataset. Specifically, a function was predicted to forecast the value labels on the testing data. The particular dataset element must be accurately selected for a good forecast to significantly impact the prediction process and result. In this vein, the variable composition within the dataset must be carefully examined for accurate prediction.

IV. Critical Evaluation

The approach towards analytical design development was utilized to evaluate aging adults with notably high BMIs. Based on a finding that paralleled multiple modeling, the currently-utilized model only supported a single classification with accuracy as low as 83%. The models reflected overfitting dataset issues in predicting the accuracy and misclassification of rare disease detection. Additionally, the data findings and methods became unbalanced with multiple classifications. A significant correlation was identified between obesity and frailty regardless of the classification. This study primarily aimed to examine how obesity affected physical frailty, diseases, and aging men and women's health through the sarcopenia-physical frailty link. This research did not define the differences between Obesity Frailty (OF), Non-Obesity Frailty (NOF), Obesity Non-Frailty (ONF), and Pre-Frailty (PF) but the research explored the expansion of differences between OF, NOF, ONF, and PF. The study parameter types with specifications only included age, BMI, physical activity, protein and meat intake, body composition, fat mass, and disease types.

V. Analytical Approach

The study data were pre-processed and prepared for the following steps using Excel and RapidMiner. Role-oriented attribution ("label" or target variable) informed the predictive models of attribute prediction. The "set role" operator sets the role attribute to identify the key determinants of obesity with the highest accuracy. The dataset was split into two components (train and test) post-role-definition. Dataset splitting proved necessary as the predictive model must learn from the training set to be applied to the test for performance evaluation. The train and test datasets were split into 70:30. Specifically, 70% represented the train datasets while 30% reflected the test counterpart. The training set typically encompassed more data than the test counterpart as the model could learn from the data for improved accuracy. Fewer training datasets implied lower opportunities for data learning and exploration.

Phyton programming was utilized to split and feed data into the selected predictive model once the role (decision tree) was set. The decision tree model was selected as the predictive model to demonstrate the chain relationship between attributes and final result for a clear depiction of obesity contributors and the individuals at risk of becoming obese in the future. The "performance" operator was utilized to assess model performance with accuracy as a criterion. Although the accuracy model demonstrated precision, the manipulated variable reflected the attributes that increased obesity risks. The predictive model accuracy on the obesity dataset was 92.95% for “breathing difficulties”, 96.81% for “heart attack”, 86.45% for “hyperlipidemia”, and 99.47% for “psychological stress”. All four attributes were selected as the most accurate obesity predictors. Consequently, each data was incorporated into modeling and ultimately defined each characteristic table regarding the accuracy outcome among classifiers.

VI. Experimentation and Result Evaluation

This section discusses the experiments and results for all five study classifiers (Naïve Bayes, logistic regression, random forest, decision tree, and KNN) Different comparisons and analyses are also discussed in this section. The high-performance approaches predicting obesity frailty are also highlighted. Notably, accuracy, precision, recall, and FI measures were utilized in the comparison.

A. Dataset Splitting

The pre-processing steps for the study dataset were described in the preceding section. The dataset must be divided into training and testing upon the completion of pre-processing.

B. Experiments and Results

Table II presents the accuracy attained by all five classification predictive models: Naive Bayes, logistic regression, random forest, decision tree, and KNN. The best-performing model among the five predictive counterparts was logistic regression. Specifically, logistic regression denoted the only model with the highest number of accuracies predicted (see Table II). Logistic regression denoted the most appropriate model to predict obesity and frailty among elderly individuals.

The analytical design approach was utilized to evaluate raw data with parameters, such as age, BMIs, physical activity, protein and meat intake, peanuts, and the composition of body, body fat, and fat mass. The OPF model encompassing naive bayes, logistic regression, random forest, decision tree, and KNN were applied to four different target attribute types: “OF”, “ONF”, “NOF”, and “PF”. The most accurate models for OF were logistic regression and KNN with 70.83% accuracy. The model would attain high accuracy by predicting high genuine and low false data with 89.81% accuracy.

Notably, the decision tree outperformed all other five models by predicting the highest true values for the NOF counterpart. Meanwhile, ONF was predicted by logistic regression and KNN (see Table III).

TABLE II. Comparison of Five Classification Predictive Models

Classifiers (%)	Obese and Frailty	Non-Obese and Frailty	Obese and Non-Frail	Pre-Frailty
Navie Bayes	**51.36**	**41.2**	**62.5**	**97.69**
Logistic Regression	**70.83**	**78.24**	**89.81**	**97.69**
Random Forest	**68.06**	**79.63**	**87.04**	**97.69**
Decision Tree	**68.98**	**82.87**	**86.57**	**93.37**
K-Nearest Neighbour	**70.83**	**76.39**	**88.89**	**90.74**

TABLE III. The OPF Model

Current Models	Methods	Parameters used	AUC
OF	Logistic Regression KNN	**Age, BMI, physical activity, protein intake, meat intake, peanut, body composition, body fat, fat mass, diabetes, hypertension, Hyperlipidemia**	70.83
NOF	Decision Tree		89.81
ONF	Logistic Regression		89.81
PF	Naïve Bayes Logistic Regression Random Forest		97.69

The modeling implied that logistic regression and Naive Bayes offered the lowest prediction for false positives and negatives. Logistic regression earned the highest accuracy of 89.81% by predicting the truest data and minimal erroneous data. The confusion matrix for PF prediction demonstrated Naive Bayes and logistic regression to have the largest true positives, whereas the decision tree highlighted the highest true negatives. The least false positives were predicted by the decision tree while the least false negatives were forecasted by Naive Bayes and logistic regression. Naive Bayes, logistic regression, and random forest were the most optimal models that predicted PF patients with 97.69% accuracy.

Fig. 2 depicts the receiver operating characteristic (ROC) curves produced for obese and frail subjects. It was deemed possible to judge the ROC curve performance based on the closeness to both the left and top borders of the curve. Regarding obesity and frailty prediction, five algorithms were tested against one another. Logistic regression was found to be the most accurate model compared to other predictive counterparts.

Fig. 3 depicts the logistic regression model. Compared to random forest, the ROC curve was more closely associated with the left and top plot bounds. The test was performed when the curve was closer to the 45-degree diagonal of ROC space compared to when the curve was further away.

Regarding logistic regression, the ROC curve in Fig. 4 presents the trade-off between sensitivity (TPR) and specificity (1-FPR). Classifiers with curves that neared the top-left corner indicated higher performance compared to the decision tree. A curve closer to the 45-degree diagonal of ROC space indicated a less accurate test.

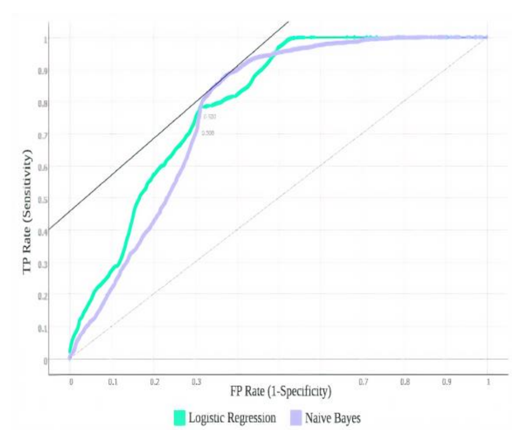

Fig. 2. The ONF ROC Curve (Logistic Regression and Naive Bayes).

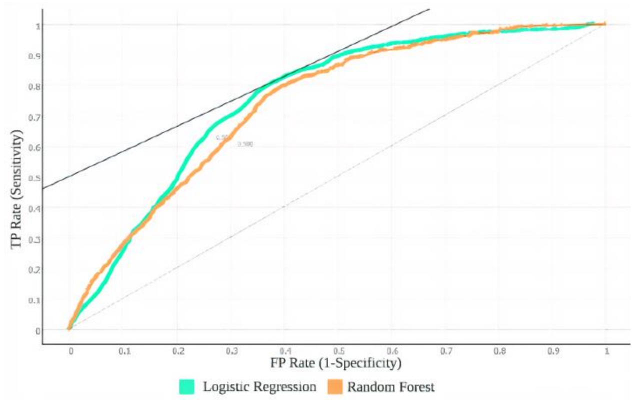

Fig. 3. The of ROC CURVE (Logistic Regression and Random Forest).

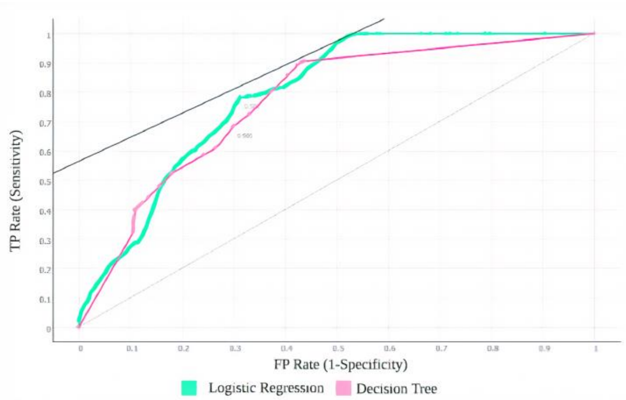

Fig. 4. The of ROC Curve (Logistic Regression and Decision Tree).

In Fig. 5, all four figures depict the logistic regression ROC curve to be closer to the left and top plot boundaries. The ROC curve for KNN was the poorest as the KNN-logistic regression gap was the widest. The ROC analysis above demonstrated logistic regression to have the best true positive rate among the remaining algorithms while the false positive rate was low. The logistic regression accuracy was higher as high true positive and low false positive rates highly contributed to the degree of model accuracy.

Overall, the obese elderly (OE) group demonstrated a higher average lean mass (LE) compared to the remaining two groups. An increase in fat mass rather than lean mass occurred during middle age. Height loss (primarily in the spine), loss of muscle mass, increase in fat mass, central, abdominal, and muscle fat, and bone loss due to aging required due consideration. Both fat and muscle loss occurred in later stages as a sign of vulnerability. The life expectancy process occurred in catabolic life with sarcopenia. The condition also reflected composite variables that were interconnected with one another. The body composition altered over 30 years with changes in weight and fat-free muscle.

Regarding obesity in Fig. 6, the clinical definition of frailty implied individuals with low and extremely high BMIs to have higher frailty levels compared to people with normal or high BMIs. Regarding higher frailty levels among people with large waist circumferences, adiposity in the abdomen appeared to be associated with high risks. The BMI-frailty association held constant across various term definitions with specific parallels between both elements that could be considered while examining the relationship. Low stress resistance from a single variable change could be interpreted as aging or high mortality risk following changes in hundreds of components [21]. For example, the mortality risks associated with variables were typically U or J-shaped [21]. A U-shaped association existed between age and the BMI risks of unpleasant outcomes and factors in most physiological systems [22]. At the cellular level, numerous systems that deactivated adaptive responses to protect age and BMI exhibited U or inverted U-shaped responses [23]. Although the data did not demonstrate scale invariance, the frailty "risk state" was associated with age and BMI.

Based on the findings in Fig. 7, comparisons between OF and hypertension OF reflected a higher level of hyperlipidemia than hypertension. Lastly, hyperlipidemia was the most chronic issue among ONF, whereas hypertension was the most prevalent condition among PF (189 respondents). The added impact of lower-extremity obesity on frailty was discovered among older adults, thus highlighting the essentiality of regular physical activities as an alternative. Predictably, abdominal obesity among older people with low BMIs would become a novel therapy target in the future parallel to the study findings. Increased physical activities could reduce belly fat [42] while endurance through exercise training could develop mitochondria [41]. Notably, physical activity benefits could be due to reduced belly adiposity and enhanced oxidative activity (independent of weight loss benefits) [41].

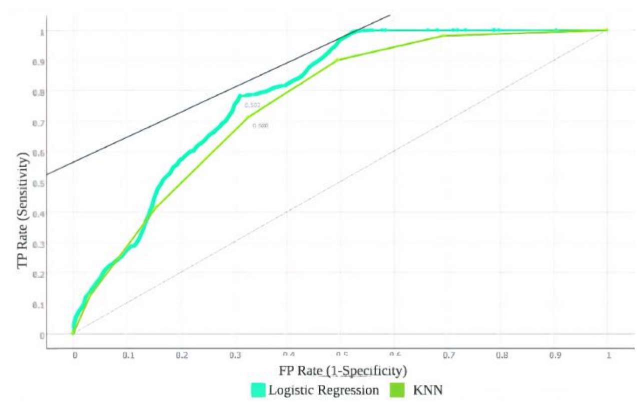

Fig. 5. The of ROC Curve (Logistic Regression and KNN).

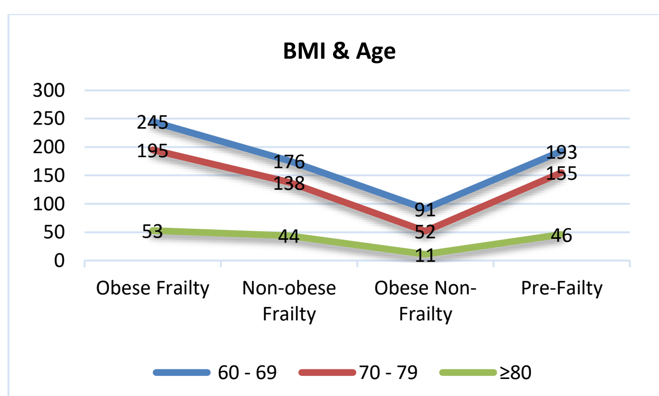

Fig. 6. The of with Aging Individuals Aged 60 and Older with Bmi and Degrees of of.

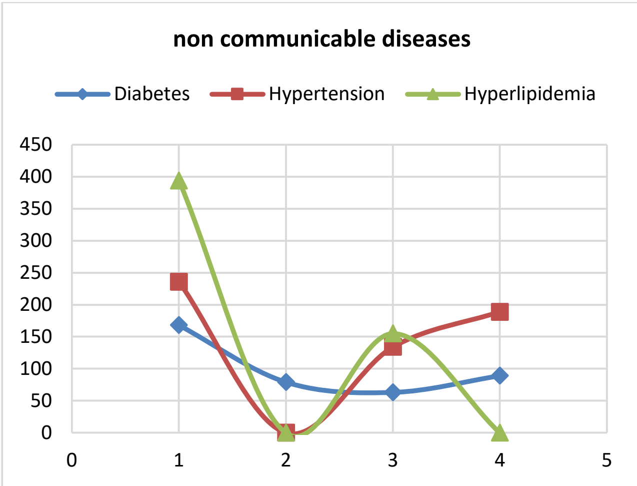

Fig. 7. The of Proportion through Non-Communicable Diseases with of Levels.

It was deemed essential to understand the frailty-obesity relationship and the criteria validity utilized to categorize the factors. Specific interventions, such as weight loss and exercise among older adults could alleviate frailty with a direct impact on the downstream implications of central obesity [29, 30]. As distinct entities, PF, frailty, and obesity were related to impairment, high healthcare usage, institutionalization, and premature total mortality [29]. Resultantly, physical activity and contributors of age, BMI, physical activity, protein and meat intake, peanuts, body composition, body fat, fat mass, diabetes, hypertension, and hyperlipidemia demonstrated the strongest connection to frailty with a potentially superior predictor of frailty risk in the OE population. The simple anthropometric measure might be easily and affordably incorporated into clinical procedures and provide prognostication among older people.

Regarding the overall test scores in Table IV, the logistic regression model yielded higher scores than neural network, random forest, and SVM. Concerning the highest accuracy, logistic regression generated more area of curve (AUC), CA, F1, precision, and recall scores. Conclusively, logistic regression predicted fewer false positives and negatives compared to other algorithms.

Fig. 8 depicts a conceptual overview of the obesity-frailty relationship, diseases, and lifestyles. Failure of heart muscles and blood vessels, diabetes, hypertension, and heart diseases were all associated with obesity and frailty. Subsequently, obesity and frailty were connected to related diseases and lifestyle factors. Active people consumed highly-sugared beverages, peanuts, and red meat and watched television for longer periods, thus contributing to obesity. Weight gain that affected various organs implied obesity. Additionally, aging bodies eventually degraded and posed high-risk and adverse health outcomes. Both combination levels led to various diseases and lifestyle-related health complexities and caused exhaustion, perspiration, anxiety, irritability, and joint and back pains that prevented sleep.

TABLE IV. OVERVIEW TEST SCORES OF THE PREDICTIVE MODELLING

Model	AUC	CA	F1	Precision	Recall
Logistic Regression	**0.982422**	**0.950463**	**0.948411**	**0.948032**	**0.950463**
Neural Network	**0.963104**	**0.941204**	**0.938094**	**0.937523**	**0.941204**
Random Forest	**0.950443**	**0.933565**	**0.922497**	**0.933513**	**0.933565**
SVM	**0.940531**	**0.936111**	**0.925756**	**0.936804**	**0.936111**

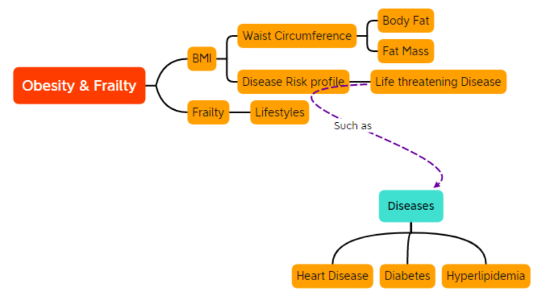

Fig. 8. Conceptual Model of Relationship with Diseases and Lifestyles (OPF).

Regarding the study limitations, it was deemed impossible to establish a causal relationship between the clinical variables and study outcome due to the restrictive cross-sectional study design. The study results were not generalizable as the sample represented a specific community. In this vein, logistic regression studies should be performed to further investigate the relationships and confirm the transition between frailty levels parallel to the case severity and reversibility in medium and long terms.

VII. CONCLUSION AND FUTURE WORK

This study aimed to create and apply a model that differed from current models by including obesity-related diseases and physical frailty. The present models only facilitated single classification with accuracy as low as 83%. Resultantly, the proposed model reflected 97.69% of accuracy and was associated with physical frailty and obesity. The OPF conceptual model was also introduced in this study. With a corresponding improvement in the logistic regression outcomes, optimal results were obtained in bridging the research gap. Current and novel approaches to machine learning fulfilled the demand for advanced and high-level prediction and description by utilizing both established and emerging machine-learning methods. Future studies intended to include logistic regression and neural network that involved participants to achieve higher accuracy. The same data were also recommended to predict and create novel modeling against OPF.

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Adaptive Continuous Authentication System for Smartphones using Hyper Negative Selection and Random Forest Algorithms

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***Abstract*—As smartphones have become a part of our daily lives, including payment and banking transactions; therefore, increasing current data and privacy protection models is essential. A continuous authentication model aims to track the smartphone user's interaction after the initial login. However, current continuous authentication models are limited due to dynamic changes in smartphone user behavior. This paper aims to enhance smartphone user privacy and security using continuous authentication based on touch dynamics by proposing a framework for smartphone devices based on user touch behavior to provide a more accurate and adaptive learning model. We adopt a hybrid model based on the Hyper Negative Selection Algorithm (HNSA) as an artificial immune system (AIS) and the random forest ensemble classifier to instantly classify a user behavior. With the new approach, a decision model could detect normal/abnormal user behavior and update a user profile continuously while using his/her smartphone. The proposed approach was compared with the v-detector and HNSA, where it shows a high average accuracy of 98.5%, a low false alarm rate, and an increased detection rate. The new model is significant as it could be integrated with a smartphone to increase user privacy instantly. It is concluded that the proposed approach is efficient and valuable for smartphone users to increase their privacy while dynamic user behaviors evolve to change.**

***Keywords*—Continuous authentication (CA); artificial immunes system (AIS); negative selection algorithm (NSA); random forest algorithm (RFA); smartphones**

I. Introduction

According to the Global System for Mobile Communications Association (GSMA) Intelligence Reports, there are more than 5 billion smartphone users in the world today [1]. Smartphones are the most sensitive and essential device in all aspects of our life, including memories, sensitive data, buying, education, and work. Consequently, there is a high need to increase the privacy and security in smartphones by authentication models. The traditional authentication methods in smartphones depend on PIN authentication approaches, known as entry-point authentication, as they authenticate the user only at the beginning of a particular session. Generally, the entry-point authentication models include PIN authentications, passwords, or biometrics; however, these models are considered discontinuous because they do not track smartphone access while interacting with the system.

Therefore, smartphones could have adversarial attacks after the initial authentication if such authentication models are adopted. On the other hand, continuous authentication keeps a consistent track of a smartphone's access over time. Continuous authentication has attracted researchers' attention in recent years to secure computers, the Internet of Things (IoT), and mobile phones, where they are commonly used to solve a device authentication problem after user login. Therefore, methods that use extensive logging in features such as behavioral biometrics (such as touch dynamics, keystrokes, movement, walking, and daily activity) are critical to continuous authentication [2].

Despite the ever-increasing number of continuous authentication approaches, there is still a need to develop new techniques applicable in real life where a device owner does not operate with the smartphone continuously. However, there are many open issues in the current continuous authentication studies, including the lack of real-world dataset, the need for increased accuracy, low usability of current models, and lack of adaption of proposed models [3].

One of the prevalent biometric behaviors of smartphone users is touch dynamics, a promising approach recommended by many researchers because it requires no additional hardware to collect information; it has high usability and robust security [3-6]. While biometrics are easy to observe, once breached, they cannot be modified or revoked. It is necessary to lift fingerprints from smooth surfaces (such as smartphone screens or coffee cups). However, the increased proliferation of high-resolution cameras raises the threat of imaging from a distance.

According to the literature, hackers gained access to the German ministers of defense Ursula von der Leyen, using just a couple of high-definition pictures. Therefore, this case undermines the finger's protection since fake fingers may be produced from other materials [7]. Therefore, biometric behavior authentication has several challenges. Mahfouz et al. [2] address the challenges, capabilities, and restrictions associated with biometric behavior authentication. One of the main reported challenges was the intra-class variations between individuals due to the user changing behavior over time; therefore, the user data in the enrollment phase (active use) may vary from the recognition phase (classification). Consequently, a proper continuous system must adhere to the challenges to prevent adversary attacks.

This paper aims to develop a model for continuous authentication (CA) using Hyper Negative Selection Algorithm (HNSA) and the random forest ensemble classifier (boosted) to authenticate and detect illegal smartphone users. This model will be enhanced to be self-adaptive to changes in user behaviors. The proposed approach starts with an ensemble learning model that enhances the performance of HNSA by applying the random forest algorithm in the testing phase (of the HNSA) to maximize the accuracy and improve the prediction to decide the user data type in the model as normal, abnormal, new normal, or new abnormal. Therefore, the proposed Random Forest Negative Selection Algorithm (RFNSA) can adapt by updating continuous data as users interact with the smartphone.

This paper is organized as follows: presents a background of smartphone authentication and negative selection algorithms in Section 2. The Foundation of the artificial immune system shows in Section 3. Section 4 presents the related works to this study. The methodology of this work is discussed in Section 5. The results obtained are illustrated in Section 6. The results are discussed in Section 7. The last section concludes the paper and presents limitations and future work.

II. Background and Related Work

A. Smartphone Authentication System

This study classifies authentication systems into continuous or discontinuous models based on how they track user interaction during smartphone usage.

1) Discontinuous authentication systems: The mobile authentication process could be categorized into three different categories: knowledge-based, possession-based, and identity-based authentication models [8]. Knowledge-based models depend on patterns that a mobile owner knows, such as passwords (such as a PIN or passcode). A possession-based model is based on an attribute that the owner has, such as a key to a lock or One-Time Password (OTP) [9], while identity-based authentication is based on something that identifies the mobile owner. Literature refers to combinations of authentication methods to a smartphone as authentication factors (AF).

Regardless of which category is used, the passcode of possession-based models is considered an entry-point authentication method as it does not follow the user's actions while the user is not actively using the smartphone. Passwords in smartphones could be in three forms: textual, digital, or graphical. On the first hand, a textual password consists of a single or intentional mixture of letters (A-Z), digits (0 to 9), symbols. A PIN (or a digit passcode) consists of numerical symbols with a typically 4–6-digit PIN as a common authentication factor. On the other hand, the graphical passcode consists of either a drawing (e.g., DooDB) or a linked dot series on a virtual grid interface [10]. The different authentication techniques could be used in smartphones, namely, slide lock, number lock, graphical-based passwords, fingerprint, and face recognition authentications [8].

However, these methods suffer from being attacked if the device is kept isolated; therefore, these discontinuous authentication methods are insecure.

2) Continuous authentication systems: Continuous authentication, also called transparent, active, or implicit authentication, is an implicit way of verifying the authenticated user using mobile system features and built-in mobile sensors that track their users' behavioral attributes [11]. The intuition behind the behavioral approach is based on the distinctive user patterns commonly used in an authentication task. While users interact with their smartphones, the device implicitly captures their interaction with the device, including user touch patterns, environmental and sensory data [12], [13]. The collected user's behavioral data (biometrics) works without knowing or explicitly asking to enter specific data. The goal is to improve mobile security continuously and transparently throughout the entire routine session [13].

Continuous authentication differs from entry-point (or traditional) authentication by two main characteristics: continuity and transparency [2]. The continuity verifies that a user is legitimate as long as the user uses the smartphone; therefore, it is an automatic re-authentication process. The second property, transparency, allows the authentications to be executed seemingly without interrupting the user. Since a CA system continually tests logged-in users' identity, it is more reliable, easy to use, stable, and encourages schemes with several protection layers. CA methods allow multi-layers of authentication of smartphones to log in to the device down to a specific application based on preference. Researchers see a somewhat favorable reaction to multiple-level authentication schemes for mobile applications that can be a welcome addition to existing conventional mobile operating systems [14].

B. Negative Selection Algorithm

The Negative Selection (NS) is an immune system mechanism that prevents self-reactive lymphocytes from being formed. As a result, only those lymphocytes that do not strongly bind with self-antigens survive this selection process. The NS theory motivated Forrest et al. [15] to suggest a generic negative selection algorithm for detecting data anomalies. It was further extended for detecting network intrusions and using it widely in computer security and fault detection. The basic concept is to apply a collection of detectors in the corresponding space and classify the data as self or non-self. To apply NS's mechanism, the shape space U is subdivided into (S), denoted as self, and (N) for non-self.

$$U=S\cup N \text{ and } S\cap N=\emptyset. \tag{1}$$

The negative selection algorithm divided into two main stages, as shown in Fig. 1, namely, Generating detectors stage and the Detection stage. The aim of the first stage is censoring to generate the valid detectors' set by generating the random detectors. In this stage, if the random detector matches the self then eliminated. Random detectors that do not match any self-data will be store in a detector set to use in the second stage. In the second stage, called (Detection stage) the monitor of protected self-data by comparing the self-set (S) with the

Detectors set (D). If the detector matches with data, which means the data is classified as non-self.

Many families of the negative selection algorithm have been developed, which keeps the main characteristics of the first version of the negative selection algorithm proposed by [15]. However, the main drawbacks of the first version of the negative selection algorithm (classical NSA) are the time-consuming and complexity of space. The NSA is divided into two types based on data representation: binary negative selection algorithm (BNSA) and real value negative selection Algorithm (RNSA). The newest version of the negative selection algorithm proposed by Zhou and Dasgupta [16] is v-detector which is now widely used as a framework for many studies due to its advantages over the previous versions with constant size detectors. The detectors' size in the v-detector varies from one detector to another.

Fig. 2 shows the difference between constant and variable size detectors in 2D space. The grey color in the figure represents the region of self, which is using as a self-sample for data training data. The circles represent the detectors covering the region of non-self while the black holes present the non-covering area; using variable-sized detectors, the greater region of non-self-area can be filled with fewer detectors, whereas smaller detectors can fill the gaps [16].

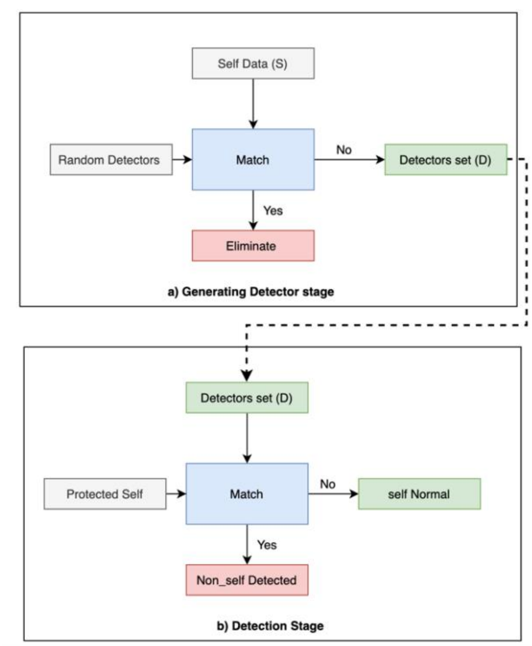

Fig. 1. The Main Stages of NSA Implementation.

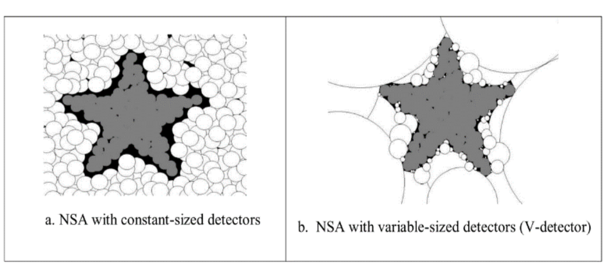

Fig. 2. The difference between Constant Size and Variable Size Detectors [16].

Recently, many NSA enhancements have been developed to address the shortcomings of the classical version, where most of them are based on how detectors are regenerated. However, not only the detector size but also its coverage is hardly achieved. Moreover, recent improvements were proposed to improve the NSA's efficiency, expand its scope, and overcome its limitations [17].

Ramdane [18] proposed an NSA-based hybrid adaptive mechanism for computer network intrusion detection called HNSA–IDSA (hybrid NSA). The proposed approach has a high ability to adaptive learning when changes happen in the system profile. The uniqueness of HNSA is that normal and abnormal self-detectors are created at the training stage by using both normal and abnormal data. In the proposed NSA's test process, its status about the *normal* and *abnormal* profile is defined by the studied sample class. The tested sample in that model's testing phase is based on its position in the system profile (normal and abnormal). Therefore, the HNSA study mechanism seems very useful to adapt system profiles when a different normal or abnormal activity is observed.

There are limited studies that apply artificial immune systems to continuous authentication in smartphones. The work of [19] demonstrated that NSA is an approach that is very appropriate for continuous authentication for PCs. The negative selection method can regularly track any changes in the environment, depending on the computer system owner's interaction. The researchers included both mouse, keystroke users' biometric activities and evaluated the suggested NS's precision; the highest reported accuracy was 99.7%. To the researchers' knowledge, the first continuous authentication method that is based on the AIS class of algorithms was by [20]. They proposed a CA method based on AIS using the Clonal Selection (CS) algorithm for smartphones. The suggested approach was extended to a dataset of screen touch patterns on smartphones; they performed the CS experiment and got 93.81% average accuracy.

III. Methodology

This paper builds a model for continuous authentication (CA) by applying the NSA on the dataset of [21], [22]. To make the model in high adaptability, the proposed model, Random Forest Negative Selection Algorithm (RFNSA), is an enhanced version of the Hyper Negative Selection Algorithm (HNSA) by applying the random forest algorithm to maximize the accuracy and improve the prediction to decide the data type in the model as normal, abnormal, new normal, or new abnormal. The proposed approach (RFNSA) can adapt by updating continuous data as users interact with the smartphone. As shown in Fig. 3, the research framework has four phases: Data preparation, Training, Testing, and Decision.

A. Data Preparing Phase

The proposed model (RFNSA) requires both positive (*normal*) and negative (*abnormal*) data samples to generate the user profile. Every user has their behavior, which identifies their identity.

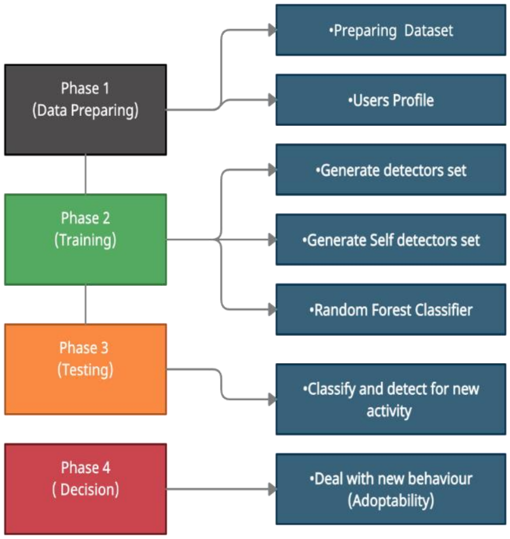

Fig. 3. Research Methodology Procedures.

The user profile contains normal behavior and abnormal behavior. Due to the advantage of negative selection algorithm (NSA), it only needs positive data to detect the identity of the user. The abnormal behaviour generated using v-detector algorithm. This paper focuses only on the first eight features of the adopted dataset (pressure, size, touch major, touch minor, duration, fly time, shake, and orientation) as shown in Table I.

For example, the area covered by the user touch (size) and the time duration (pressure) could detect user behavior. These behavioral characteristics help to understand the user's interaction with the smartphone. Because the features have different ranges value (scales), there is a possibility that higher weighting would be assigned to features with higher magnitude, which might affect the performance of the algorithm. Therefore, values were normalized to be in the range of (0 and 1), often defined as minimum/maximum scaling. A new column was added to the dataset, a label of 0 for self and 1 for non-self. Once data is prepared, the dataset was split into 70% for training and the rest of the data for testing and evaluating model performance.

B. Data Training Phase

1) Initial training: After the dataset preparation and generating user profile, the second research procedure is training phase that is divided into two sub-phases: initial training (to cover the non-self-area with non-self-detectors) and further training (to cover the self-area with self-detectors). The role of the initial training is to generate the non-self-detectors set, whereas generating the self-detectors set is executed in further training sub-phases.

The purpose of this procedure is generating the non-self-detectors set. The v-detector is an enhanced version of the NSA with control parameters: the self-radius, estimated covering, and maximum number of detectors [16]. In this algorithm, the random detectors are generated—the detectors produced by randomly generated numbers (candidates' detectors) one by one. The Euclidean distance between the random detectors and a self-point is calculated to recognize its relation. The shortest distance indicates high affinity, which means the detectors match the self-point. The detector is eliminated, and a new random detector is created if the distance to the nearest self-point is less than the value of the self-radiusr_s. If the minimum distance between the random detector and self-point is more than the self-radiusr_s, the detector is temporarily stored. The radius of this detector is recorded as r_d with the value of minimum distance to the nearest self-point. As shown in Fig. 4, represent how the detectors in shape space with variable size to cover non-self-area region.

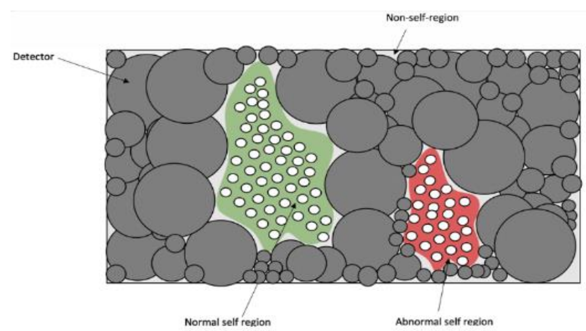

Fig. 4. Normal and Abnormal Regions.

TABLE I. A SAMPLE OF USERS' DATASET

#	Pressure	Size	Touchmajor	Touchminor	Duration	Flytime	Shake	Orientation
0	0.738576	0.433604	9.063023	3.287221	300.8392	145.5518	907.933743	1
1	0.490881	0.493693	4.220438	9.336123	635.8852	484.2957	588.150531	1
2	0.810864	0.493129	6.970505	9.831867	188.5718	464.8582	963.755181	1
3	0.474932	0.355566	2.63251	2.806116	979.9968	638.5064	245.999725	1
4	0.100484	0.184131	2.32429	6.395209	436.6558	653.1836	410.864218	1
...	...	...	...	...	...	...	...	...
96171	0.093137	0.084314	14.32297	14.32297	76	388	47.40989	1
96172	0.118954	0.045752	7.772156	7.772156	64	0	28.167099	1
96173	0.103268	0.047059	7.994217	7.994217	67	579	52.578495	1
96174	0.084314	0.036275	6.16221	6.16221	98	1262	30.075933	1

The generating detectors process in v-detector is controlled by three parameters: radius of self-point (r_s), max number of detectors (D_{max}), and the estimated coverage (M_{max}). The last two parameters are the termination criteria. The D_{max} , are determined to allow the maximum allowed detectors that could be generated. The generated detectors are temporarily stored to check if it matches any previously stored detectors. If it is found in already stored detectors, then it eliminated, and the maximum coverage area M_{max} is incremented. If it is not stored previously, it added to the detectors set, and each time it is permanently stored detector increment the parameter D_{max} and reset the counter M_{max} to zero. If the counter of consecutive attempts that fell on protected points exceeds a limit M_{max} , the generation stage concludes with enough assurance that the coverage is adequate to protect the non-self-area [23].

2) Further training: Further training was applied to generate the self-detectors set (SD). The benefit of adopting this operation is to reduce the next phase's computational cost (testing phase). The further phase works as follows:

- Use $\boldsymbol{D}$ as a training set to generate self-detectors (SD) for the self-area; the self-detector is defined as shown in equation 2, where SND is the set of self-normal detectors, SAD is the set of self-abnormal detectors.

$$SD = SND \cup SA \tag{2}$$

- Generate random values for self-detectors; if self-detectors SD match any detectors D as shown in equation 3 wherer_d, the radius of the detector is; then, the detectors are eliminated.

$$dis(SD, D) < r_d \tag{3}$$

- If the random self-detector does not match any detector, calculate the Euclidian distance for all detectors in the training set (D) and find the minimum distances using equations 4,5 where r_{sd} is the radius of self-detector:

$$dis(SD - D) = \sqrt{\sum_{i=0}^{n}(SD - \mathrm{D})}^{\,2} \tag{4}$$

$$r_{sd} = MinDis(SD, D) \tag{5}$$

- Add a detector to the self-detectors' set, SD, with a label that indicates the type of detector. If the detector is situated in a normal region, it is labeled normal (0); otherwise, it is labeled abnormal (1).
- In this stage, all self-sample and generated new self-detectors will be considered self-detectors with two types (normal self-detectors and abnormal self-detectors).

C. Testing Phase

Random Forest Algorithm (RFA) is a supervised learning algorithm that is a more precise forecast. The basic concept of RFA is to ensembles many decision tresses to vote the best prediction. In the proposed enhanced model, training is carried on the training data to enhance the model performance to predict the data type (normal or abnormal). The random forest has many advantages that make it an excellent choice to apply it to the proposed model, such as high accuracy, quick prediction, fast training, and the ability to handle unbalanced data to minimize the error rate. The work of [18] applies this procedure to classify the income data and detect new behavior in IDS.

This research follows up the same steps with engaging the random forest classifier to enhance the preprocessed data classification, in this phase, the process using self-detectors (SD) which contains self-normal detectors (SND) and self-abnormal detectors (SAD) with test sample set (T) following equation 6.

$$SD = SND \cup SAD \tag{6}$$

To classify the test sample data type, the distance between the test sample points (t) to self-detectors (SD) is calculated as shown in equation 7, which is used to decide the data type as known abnormal, known normal, new abnormal, or new normal.

$$dis(t - SAD) = \sqrt{\sum_{i=0}^{n}(\mathrm{t} - \mathrm{SAD})}^{\,2} \tag{7}$$

$$mindis(t - SAD)/r_{asd} \leq 0.9 \tag{8}$$

If $\mathrm{dis(t - SAD)} < \mathrm{r_{sad}}$ where $\mathrm{r_{sad}}$ is the radius of abnormal self-detector, then the prediction is checked from a random forest classifier; if it is the same (abnormal), then an additional condition is added (equation 8) to make sure the sample t in the abnormal region. If all conditions are met, the data type is known abnormal; otherwise, the data type is one of the remaining three types.

$$dis(t - SND) = \sqrt{\sum_{i=0}^{n}(\mathrm{t} - \mathrm{SND})^{\,2}} \tag{9}$$

$$mindis(t - SND)/r_{nsd} \leq 0.9 \tag{10}$$

If $\mathrm{dis(t - SND)} < \mathrm{r_{nsd}}$ where $\mathrm{r_{nsd}}$ is the radius of the normal self-detector, then the prediction is checked from a random forest classifier; if it is the same (normal), then an additional condition is added (equation 10) to make sure the sample t in the normal region. If all conditions are met, the data type is known normal; if there is no match, the data type will be one of the remaining two data types.

If any self-detectors do not cover t, the model classifies it as new normal or new abnormal based on the nearer region to this point t.

$$if(Mindis(t, SAD) - r_{asd} \leq Mindis(t, SND) - r_{nsd} \tag{11}$$

If the condition in equation 11 met, then the t is considered abnormal because it is nearer to the region of abnormal more than the normal region.

$$if(Mindis(t, SAD) - r_{nsd} \leq r_d \tag{12}$$

where $\mathrm{r_d}$ is the radius of detector, then new abnormal is added to SD, and it is labeled as abnormal with the radius size detector $\mathrm{r_d}$ as a radius of new abnormal; otherwise, new abnormal label is added to SD with the radius of nearest self-abnormal detector $\mathrm{r_{sad}}$ as a radius of new abnormal.

$$if(Mindis(t, SND) - r_{snd} \leq Mindis(t, SAD) - r_{asd} \tag{13}$$

A new normal behavior is detected if equation 13 met, then t is considered normal because it is the nearest to the normal region compared to the abnormal region.

If $(\mathrm{Mindis}(\mathrm{t}, \mathrm{SND}) - \mathrm{r_{snd}} \geq \mathrm{r_d}$ where $\mathrm{r_d}$is the radius of the detector, then new normal to is added to the SD, and it is labeled as normal with the radius size of the detector $\mathrm{r_d}$as the radius of new normal ; otherwise, new normal label is added to the SD, with the radius of the nearest self-normal detector $\mathrm{r_{snd}}$ as the radius of new normal.

To summarize, the proposed algorithm enhances the performance of HNSA by applying the random forest algorithm in the testing phase to maximize the accuracy and improve the prediction. The new approach decides the data type in the model as normal, abnormal, new normal, or new abnormal as follows:

- Train random forest model on self and non-self-data. The random forest will predict the data type (normal or abnormal).
- Predict the test data type to either (normal or abnormal).
- Add a condition to the model to calculate the relation between $\mathrm{dis}(\mathrm{t} - \mathrm{SAD})$ and $\mathrm{r_{sad}}$; if the values are not very close, then the first case is applying (known Abnormal). Additional conditions are added to the model to study the relation between $\mathrm{dis}(\mathrm{t} - \mathrm{SND})$ and $\mathrm{r_{nsd}}$; if the values are not very close, then the second case is applying (known normal).

D. Decision Phase

The decision module responds to update the user profile with a new normal or a new abnormal behavior. If the abnormal data is in the user's profile, then immediately the phone is locked, or the user is silently permitted to continue using the phone. If the user behavior has little change, then this behavior is added to the user's profile. The new addition helps the model adapt to user change behaviors repeatedly and detect the new user behavior if the same situation reappears. By this, the adaptability is enhanced aiming to deal with user change over time when the user behavior indicates a new abnormal or new normal behavior.

By updating the data that comes from user interactions with the smartphone, the modified approach, RFNSA, can detect and adapt to changes in the user profile based on new-normal or new-abnormal experiences. The proposed conceptual approach, as shown in the Fig. 5, begins by collecting behavior features of a user touch screen for a specific period used for training. A user profile builds from the previously collected data. After a user profile is established, while the user uses his/her smartphone, the extracted features are processed to detect a user identity continuously.

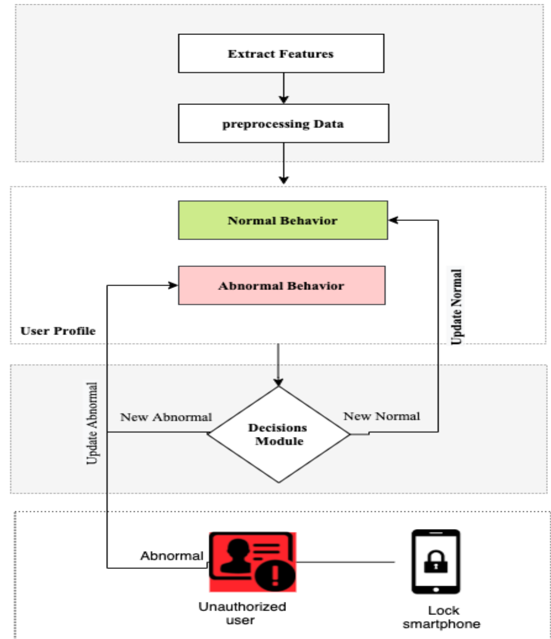

Fig. 5. The Structure Diagram of the Proposed Approach of CA in Smart Phones.

IV. Result

The generated detectors in preparing dataset phase depend on control parameters: radius of self-point (r_s), max number of detectors (D_{max}), and maximum estimated coverage area (M_{max}). The initializing of control parameters affects on generating detector and overall performance. Table II shows the effect of control parameters on proposed algorithm performance.

Due to the high randomness of the v-detector algorithm, many tests were performed for each of the experimental tests; thereby, the experiment took the average value of the number of detectors generated (D (mean)), execution time, and accuracy. Many tests are conducted to choose the optimal value of (D_{max}). Due to the advantages of the nature of v-detector, which is variable-sized detectors to cover the covering area with few detectors, this experiment tests the best value for max number of detectors (from 10 to 22) and noticed that the less number of detectors leads to fast execution without affect the less number of detectors leads to fast execution without effect on the overall of accuracy. The value of D_{max} chosen for this experiment is 16. As described in Table II, a smaller r_s increases the execution time and increases the number of generating detectors.

This experiment uses 90% of the estimated area by using the value of M_{max}=10 in order to make balance on accuracy and less execution time. The non-covering area is $1/m$ = 0.1 from the whole non-self-region, while the maximum number of detectors, D_{max} was 16. The non-self-detectors were generated multiple times to make adequate negative data of the negative sample of users' behavior profile. Approximately 500 records were generated for each user. That is the data building from non-self-detectors not matching the positive data (*normal* behavior).

TABLE II. EFFECTS OF CONTROL PARAMETERS ON GENERATING DETECTORS

r_s	M_{max}	D_{max}	D (mean)	Execution time (s) (mean)	Accuracy
0.1	10	16	16	33.69	99.20
0.2	10	16	17	33.53	99.74
0.3	10	16	16	30.13	99.13
0.4	10	16	11	49.45	99.10
0.01	10	16	18	94.75	96.20
0.02	10	16	15	83.12	97.30
0.03	10	16	12	79.67	96.90
0.04	10	16	17	65.19	99.10

The proposed RFNSA uses *normal* and *abnormal* data for users as (self-set). In this experiment, the dataset split into 70% for training and 30% for testing. The RFNSA model starts with generating the non-self-detectors using the v-detector algorithm described previously. The non-self-detectors set with their radius are used in the next stage to generate the self-detectors. The non-self-detectors were generated using control parameters (r_s=0.2, D_{max}=16 and M_{max}=10), as they were the best performing in terms of average accuracy and execution time.

Similarly, the self-detectors were generated in the same manner using the v-detector; the generated detectors have to match with self-point and not to match detectors from previous procedures. The goal of this stage was to cover the self-area with detectors. At the end of further training, all training data with the generated self-detectors were considered self-detectors, which have two types: normal self-detector (SND), and abnormal self-detectors (SAD). The proposed RFNSA adds additional training to the HNSA with random forest to enhance the model prediction to decide the user's behavior as normal (label 0) or abnormal (label 1). This study used the sklearn library implementation of the random forest classifier on the training dataset. The random forest classifier performance is shown in Fig. 6, which gets a maximum average accuracy of 99.9%. The random forest algorithm is used in the testing phase later to predict the type of data.

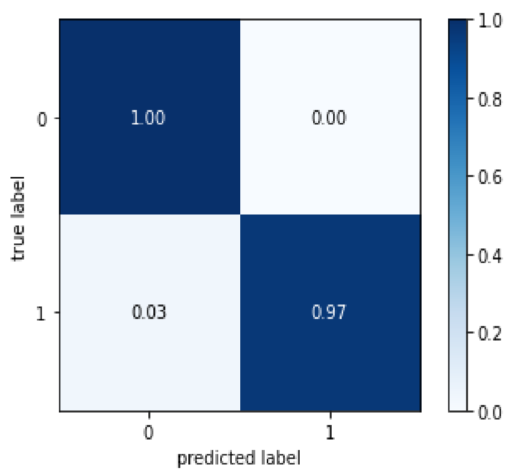

Fig. 6. Confusion Matrix for Random Forest Classifier.

The testing stage classifies the test data into normal or abnormal and detects new user behaviors. As shown in Fig. 7, for the 8th user and out of 2,102 records, the proposed algorithm detects 144 records as new abnormal behavior and 1,941 records as new normal behavior. All those new behaviors were added to the dataset to be recognized next time, which means applying adaptability.

Table III represent the (normal and abnormal) data for each user. As noticed from Table IV**,** the model success in detecting user behavior. The highest error ratio in the classification of test data in user 11 and user 20, where user 11 incorrectly identify about 29 new normal records as new abnormal with error ratio (1.378%), and user 20 identify 6 records from abnormal test data as new normal with error ratio (0.285%).

An efficient authentication system should have a high detection rate (DR) and low false alarm rate (FAR). This paper uses accuracy and detection rate together with false alarm rate to evaluate the model's performance. Due to the unbalanced dataset in two classes (normal and abnormal), the balanced accuracy was used by taking the recall for each class of data.

The performance of the proposed model is shown in Table V, which describes the metrics values for each user, and the average values for all users. The average values of performance metrics appeared to be more acceptable based on the findings, compared with the literature's results of continuous authentication for smartphones.

The experiment results were conducted to compare among three models (v-detector, HNSA, RFNSA). The experimentation was conducted with different self-radius values as shown in Fig. 8; the RFNSA is more stable than HNSA. The HNSA minimum accuracy was 51% when the r_s was 0.4, while the maximum accuracy was (97.7%) when the radius was 0.3.

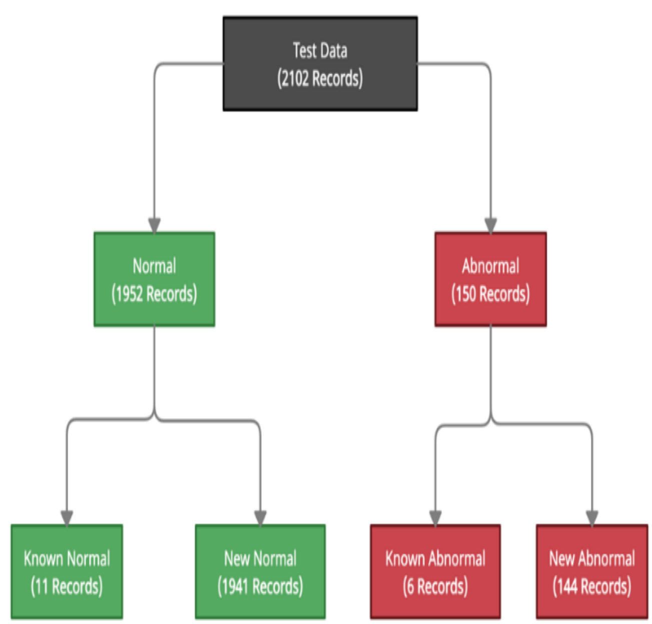

Fig. 7. Example of Classifying Test Data for user 8.

TABLE III. BUILDING USERS' PROFILES

Users	Normal Data	Abnormal Data*
1	12,095	528
2	6,506	507
3	6,506	505
4	6,506	501
5	6,506	506
6	6,506	508
7	6,635	502
8	6,506	500
9	6,506	504
10	6,506	507
11	6,506	503
12	7,196	507
13	6,506	506
14	6,506	503
15	6,506	504
16	6,506	504
17	6,635	502
18	6,506	505
19	6,506	507
20	6,506	507
Total	**136,657**	**10,116**

TABLE IV. CLASSIFYING DATA FOR ALL USERS

User	Normal Data			Abnormal Data			Classifying Error
	Test (Total)	known	New	Test (Total)	Known	New	
1	3,629	0	3634	159	0	154	0.13%
2	1,952	0	1,954	153	0	151	0.09%
3	1,952	8	1,946	151	1	148	0.09%
4	1,952	185	1,768	151	0	150	0.04%
5	1,952	19	1,935	152	1	149	0.09%
6	1,952	16	1,936	153	0	153	0.00%
7	1,952	0	1,952	152	1	149	0.09%
8	1,952	11	1,941	150	6	144	0.00%
9	1,952	0	1,951	150	1	150	0.05%
10	1,952	1	1,954	153	0	150	0.14%
11*	1,952	89	1,883	153	2	183	1.37%
12	1,952	0	1,954	153	0	151	0.09%
13	1,952	0	1,954	151	0	149	0.09%
14	1,952	0	1,954	153	0	151	0.09%
15	1,952	2	1,950	150	0	150	0.00%
16	1,952	92	1,861	150	0	150	0.05%
17	1,952	0	1952	152	0	152	0.09%
18	1,952	0	1954	151	0	149	0.09%
19	1,952	19	1935	152	0	150	0.09%
20*	1,952	35	1923	153	2	145	0.28%

TABLE V. EVALUATION METRICS FOR ALL USERS

User	Acc. (%)	Presc. (%)	Recall (%)	f1-score (%)	(DR) (%)	FAR	Balanced Acc. (%)
1	99.8	100	97	99	97.4	0.0000	98.70
2	99.7	99	99	99	97.38	0.0010	98.64
3	99.6	99	98	99	96.69	0.0015	98.26
4	99.7	99	98	99	98.01	0.0010	98.90
5	98.6	99	98	99	96.72	0.0122	97.70
6	99.1	95	99	97	98.00	0.0076	98.96
7	98.3	99	98	99	96.72	0.0122	97.70
8	98.2	99	99	99	99.00	0.0005	99.70
9	99.8	99	100	99	99.33	0.0015	98.30
10	99.7	100	99	99	97.30	0.0980	99.20
11	98.7	99	97	98	95.40	0.0204	96.68
12	99.1	100	100	100	97.30	0.0000	98.00
13	99.9	100	100	100	98.60	0.0000	98.60
14	99.7	98	100	99	99.00	0.0025	99.80
15	99.6	98	99	99	98.10	0.0025	98.90
16	99.8	99	100	99	98.30	0.0025	99.80
17	99.9	100	100	100	99.00	0.0000	99.70
18	98.2	99	99	99	98.43	0.0122	97.70
19	99.6	100	98	99	95.40	0.0000	97.70
20	99.7	100	98	99	96.07	0.0000	98.03
Avg	**99.33**	**99.05**	**98.8**	**98.9**	**97.60**	**0.0043**	**98.55**

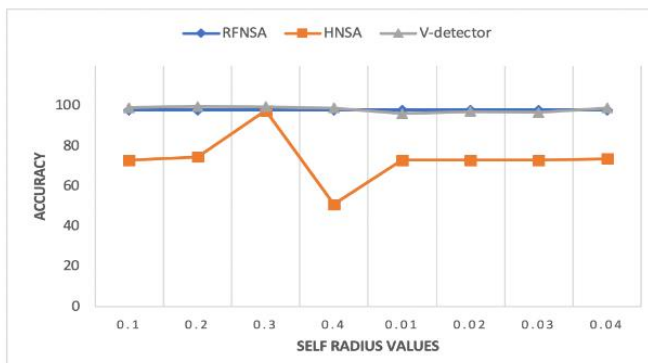

Fig. 8. Performance of RFNSA, HNSA and V-detector (Average for all users).

V. DISCUSSION

Any efficient security system should have the ability to detection for anomaly with low error rates quickly. The proposed model RFNSA would be adopted in security fields in continuous authentication systems in smartphones. This study results indicate that this model has a high ability to deal with anomaly user's behavior with self-adaptive ability to deal with changes in users' behavior. However, the current approach is yet to be taken cautiously due to the dataset and its limited features. Moreover, the model has not been applied in practice; therefore, its robustness is not yet tested. Compared with NSA, HNSA this model has robust and stable performance among various self-radius values. The proposed RFNA stability is due to the effect of the addition of the random forest algorithm and best-chosen values of r_d as $r_d = 2 * r_s$ which was based on the experimental in the HNSA[18]. In the future more values of r_d will be conducted to study the effect of varity r_d on the model performance.

The main critical issue is building a negative sample (abnormal user behavior dataset) to handle these issues; the v-detector can generate the detectors that do not match self-data. Those detectors were considered abnormal data and were generated for each user. The proposed model deals with new behavior by adding this behavior to the user profile, but this process should, in contract, deal with delete any old behavior, which is matching user behavior for a long time. The deletion of user profile data was kept for future research. Tuning the proposed algorithm to the best performance was time-consuming; therefore, based on previous research, specific values were chosen; the value for $M_{\max}$=10 to cover the whole non-self-region (90%) in a short time and $D_{\max}$=16 for the advantages of v-detectors that generate variable-sized detectors to cover the estimated coverage area quickly.

VI. Conclusion, Limitations and Future Work

A. Conclusion

In this paper, a continuous authentication framework proposed depends on touch dynamic, where users interact with their device's touchscreen. This study applies a modified version of HNSA in an ensemble classifier to detect any user behavior changes while using the smartphone. The HNSA was modified to work better for smartphones over a selected continuous authentication in smartphones' dataset.

The enhanced version is called Random Forest Negative Selection Algorithm (RFNSA). This proposed model gives a stable and efficient performance more than V-detector and HNSA algorithms. One of the framework's most advantages is that it resolves the two biggest challenges in continuous authentication: accuracy and adaptability. The model provides a balanced accuracy of (98.5%), with a high detection rate (97.6 %), low false alarm rate (0.004%), and it adapts itself while a user is using his/her smartphone.

B. Limitations and Future Work

The results obtained from this work give a high accuracy result with a high detection rate and low false alarm rate, but this work still has a limitation that opens the way for several future research possibilities. First, due to the lack of available public datasets, one dataset was used. As a potential future first step, we must comprehensively evaluate our model with more than one dataset to generalize this research's findings. Also, while a new layer was added to increase the authentication model's accuracy, the processing is increased due to the ensemble learner (the random forest). Although the extra processing of random forest might be negligible when a tradeoff is made with security, it must be integrated with the HNSA algorithm. Additionally, combining touch patterns with other behavior measurements can help characterize and verify an improved user behavior.

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Lightweight Chain for Detection of Rumors and Fake News in Social Media

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***Abstract*—Social media has become one of the most important sources of news in our lives, but the process of validating news and limiting rumors remains an open research issue. Many researchers have suggested using Blockchain to solve this problem, but it has traditionally failed due to the large volume of data and users in such environments. In this paper, we propose to modify the structure of the Blockchain while preserving its main characteristics. We achieve this by integrating customize blockchain with the Text Mining (TM) algorithm to create a modified Light Weight chain (LWC). LWC will speed up the verification process, which is carried out through proof of good history where the nodes will have the weights according to their previous posts. Moreover, the LWC will be compatible with different applications such as verifying the authenticity of news or legal religious ruling (fatwas). In this research, we have implemented a simple model to simulate the proposed LWC for the detection of fake news and preserving the characteristics and features of the traditional Blockchain. The results on experimental data reflect the effectiveness of the proposed algorithm in establishing the chain.**

***Keywords*—Component; fake news detection; text mining; blockchain; detection algorithms words**

I. Introduction

Actually, "the production of false rumors or news that might prejudice public system or security, or send or re-send them through social media or any technical means, is an information crime that carries a sentence of five years in prison and a fine of three million riyals, Noting that the sixth article of the system "fighting information crimes" Any person who commits any of the following information crimes; production that violates public order, religious values, public morals, or the sanctity of private life, shall be punished with imprisonment for a period not exceeding five years and a fine not exceeding three million riyals, or one of these two penalties, preparing it, sending it, or storing it through the information network, or one of the computers. "[Okaz Newspaper]. All this poses a big challenge for researchers, to find an effective solution to the problem of information validity and reliability.

When digital content is shared, video or pictures of any event, how can we trust its authenticity and credibility? Considering that, the public is losing their trust in media due to the absence of reliable indication of facts. The 21st century's beginning set the premise for today's disruptive digital economy, wherever creating and presenting digital content has become convenient and easy. Digital content in the form of many multimedia types of blogs is being created and published at large scales today. Fake news misguides the public or just seeking more page views to get more income by dishonestly transforming a new kind of yellow press. Whereas, putting an end to these wrongdoings has become necessary.

An instinctive way to neutralize fake news in social networks is to apply a central regulatory authority to handle the news flow. However, applying such authority requires adjusting the functional and the model of trust in social networks that is tough as it is a public and open network.

Blockchain technology is a technology that can ensure the security and reliability of various forms of information such as news. It can establish the largest distributed record that allows the transfer of ownership or the exchange of trade transactions without the need for a third party. In addition to achieving a high degree of safety and reliability. To date, this technology has only been used in the commercial and financial domains, and its applications have been limited to digital currencies, electronic payment, smart contracts, and some latest applications in medical information confidentiality.

One of the major challenges is to uphold the decentralization of social networks while limiting fake news sharing.

Our study in this paper involves:

- Analyzing and detecting the fake news on social networks.
- Verifying the source integrity of information.
- Ranking the news with an indicator of authenticity.

Due to the anonymity discussed earlier, users can validate the news feed with no pressure. Consequently, their validation cannot be biased to any agendas. After the news is published, the deployment will be in the form of a chain transaction. And then with a certain degree of vitality, validators receive a request to validate the news [2]. The validator will give value to the correctness of this news. Those values will indicate the authenticity of the news. Due to the decentralization and anonymity of the system, their verification is transparent and trustworthy. Once the verification is performed, the news will have a ranking of authenticity. These ranks will be included anywhere the news is distributed.

Our contribution is summarized by first providing a new solution to the problem of documenting and verifying news in social media applications or Islamic electronic fatwas applications. Second, we will propose a modification to the blockchain structure as the Light Weight chain, through integration with text mining algorithms. Third, we will explain how the consensus algorithm is established based on the good reputation to select the master nodes and estimating their importance in the news evaluation process. Fourth, to verify the feasibility of our research idea, we test and implement the proposed model. Fifthly, to automatically verify and create the modified string, we develop and implement the Text-Mining algorithm, and finally, we suggest a set of important future work in the field of news verification.

The rest of the article is organized as follows. In Section 2, the literature review demonstrates previous work in Section 3 and our analysis as discussion in Section 4. Then we will present our proposed framework, algorithm and presents a case for applying our idea in Section 5, and Section 6 depicts the results and evaluation.

II. Literature Review

The use of technology to detect fake news and classify it correctly is a challenging task. Researchers have made efforts to deal with this important issue. This section presents an overview of several of them, discussing their approaches, results, and effectiveness. Many studies have been published to address the problem of detecting fake news in cyberspace, such as "Detecting fake news on social media [3] is one such study. Authors claim a very high accuracy ratio of fake news detection. They used WEKA classifiers which can be described as an algorithm that evaluates the given data and generates the final result after processing [3], but there is still a confidentiality issue. In another example of Detecting Fake News from Multiple Sources and Multiple Classes is proposed in [4], called the MSMC technique for detecting fake news. The authors endeavored to solve the problem by answering two questions [4]:

- How to effectively combine information from multiple sources for fake news detection?
- How to mathematically discriminate between degrees of falsehood?

It integrates three elements of coherence in an automated form of end-to-end features: interpretable multi-source fusion, extraction, and falsity discrimination [4]. In the extraction, they use a deep model to extract characteristics from textual sources based on the CNN (Convolutional Neural Network) and LSTM (Long Short-Term Memory) [4]. The interpretable multi-source blending component aims to combine features from different sources by applying different formulas and final falsehood discrimination that is responsible for the degree of falsehood. Their model obtained 38.81% accuracy and the most notable point is the discrimination of falsehood, regardless of the minimum precision compared to other results.

The studies we mentioned above discuss the fake news detection part, but our goal is to integrate detection and Blockchain to get the benefit of them. Credibility Test: A Blockchain approach to detect and block fake news on social media [5] is the most relevant to our use case, due to the use of Blockchain in its model. The authors proposed a modification in the scheme of the social media system, to be redesigned with Blockchain technology to provide control over the news shared and back to users on a P2P network. The proposed algorithm is called Proof of Credibility, aimed at people and preventing the exchange of false news on social networks [5].

The concept of this algorithm is to redesign the architecture of social networks to be more decentralized, where users are represented in P2P communication as nodes. Each node contributes to the distributed ledger, which is identified as an immutable and cryptographically protected record of identified fake news. The authors of this article simulate their algorithm on Twitter with two hashtags, and the most interesting finding from this study is that the satisfied value of accuracy is 89% on personal fake news.

In [12] the authors proposed a new method for sharing and analyzing the news to detect fake news using Blockchain, called SANUB. SANUB provides features such as publishing news anonymously, news evaluation, reporter validation, fake news detection and, proof of news ownership. The results of our analysis show that SANUB outperformed the existing methods.

In [13] the authors have briefly explained the discussion of how cryptography and Blockchain technology can be used to detect video fraudulence and the possible way of its implementation is also discussed.

In this paper [14], researchers proposed a new Blockchain system that overcomes current challenges and limits the spread of fake news across the network by analyzing information workflow in social networks and building an optimal detection system that can be deployed effectively with minimal overhead.

Using the advantages of Blockchain's [11] peer-to-peer network concepts, researchers discussed a method for detecting fake news in social media. Their method is based on giving weight for the users to determine the probability of being selected as a validator that will be useful to rating the sources [15].

There are many research studies on detecting fake news on social media, and some research studies have used the Blockchain method for their purposes [16]. In a research study, Gilda explored the application of natural language processing techniques to detect fake news [17].

Another research work used the Naïve Bayes classifier to identify fake news [18]. A research study applied the closest neighbor algorithm to classify the news polarized from the trusted news [19]. Youngkyung Seo, Deokjin Seo, and Chang-Sung Jeong provided a model for the detection of fake news using media reliability [20]. Shivam B. Parikh, Pradeep K. Atrey conducted text analyses to uncover fake news.[21]

In research [23], one speaks of fake news and one-off news as indicated in the vector space model, combining vector display of the repetition term, the frequency and repetition of the opposite report are reversed with mutual consent 10 superpositions using the computation classifier of vector reinforcement machine [22].

Cai Shuo, Huan Liu, and Suhang Wang have formulated a dataset with accurate information [24]. They gave two news rankings (fake and real) [25-28] for two of the client meetings [29]. One meeting was from an experienced client (they could easily spot fake.

There are many mobile app for fake news detection, along with a comparison of them posted in the affiliation with this subsection. Such as: NewsCop [8], ELISA [9] and Oigetit [10] but all have used AI algorithms without integration with Blockchain in their models.

III. Discussion

We now discuss the main challenges in news validation according to existing literature and our proposed solution.

1) The huge volume of data, which makes it impossible to save an entire series in the social media space.

2) The difficulty of having this chain for every user of communication sites.

3) The difficulty of involving all users in the consensus process, which is why we have a Master Node in our proposed solution with a consensus mechanism based on proof of good history algorithm.

On the other hand, we differ from Researchers in [6, 7, and 14], which discussed ideas close to our own research. But in [6], authors have cooperated with BlockChain with AI to detect and track fake news by detecting DeepFake in videos and flagging suspicious accounts, as it relied on a group of editors to commonly supervise the process. The proposal in [7], relies on a prior definition of reliable news agencies as a source to verify other news and use the BFS algorithm in the search process. Finally, the proposal in [14] is interested in reducing the problem of re-sharing news irregularly or modifying it.

In the current research, we provide a solution to the problem of the huge size of the fake string in the news that all the research suffered from, including [6, 7, and 14]. We achieve this by enabling TM to create a modified light string, and thus at the same time providing a solution to enable a larger number of nodes to participate in the evaluation process as a master node. We suggest a special algorithm for the consensus process that fits the nature of the news and the nature of the blockchain, by linking a historical record to the reputation of the node participating in the evaluation and the final classification of the news as either true, false or true in a certain percentage.

The most important characteristics of blockchain that we have preserved in the proposed modified model are as follows:

1) It does not depend on a limited number of authorities or governments so that the system does not become semi-centralized, and this affects freedom of expression in news applications.

2) Allow readers to share news in the decision process to promote freedom and decentralization.

3) Integration of trust between people (as auditors) and trust between machines such as automated auditing, as per blockchain technology process.

4) Non-denial so that a node cannot deny its ownership of a particular block within the chain.

5) Non-modification and reliability, so that any modification to a block will be revealed at the level of the block itself and at the level of the chain of the node that did the modification process.

6) The strength of the code, or the code is the rule, that is, the node becomes a master or gains weight according to the consensus algorithm used, which is managed automatically through the software codes without administrative intervention. The most important of these algorithms are illustrated in Table I.

As shown in Table I, the comparison shows the performance of each consensus protocol where "+" means a good performance of protocol and "++" high performance where "o" means the performance is average. The characteristics of our proposed framework illustrate its strength in performance and completion.

TABLE I. A COMPARISON BETWEEN CENSUSES ALGORITHMS

Algorithm name	Principle	Performance	DLT environment	Completion	Example of use
Proof of Work (PoW)	Difficulty finding solutions with ease of verification	-	Public	probabilistic	Bitcoin, Ethereum, Litecoin
Proof of Stake (PoS)	Whoever has a greater share of validators has the potential to create blocks	+	Private & Public	probabilistic	Ethereum, NXT, Tezos
Delegated Proof of Stake (DPoS)	Producing new blocks for a small, fixed number of elected validators authorized by the participants. It has high competition, and it is very profitable.	+	Private & Public	probabilistic	EOS, BitShares
Proof of Activity (PoA)	It is a mixture between the first two protocols in terms of share and arithmetic power, providing a balance between the miners and the ordinary participants	-	public	probabilistic	Decred
Proof-of-Location (PoL)	To verify a node, its position is marked by GPS and a temporary stamp is given to it	o	public	immediate	FOAM, Platin
Proof-of-Importance (PoI)	Similar to POS algorithm with other important features	+	public	probabilistic	NEM
Proof-of-Elapsed-Time (PoET)	The blocks are created in a secure environment, which is similar to POW, except that it is from a reliable environment and has less electricity consumption	O	Private	probabilistic	Intel
Proof of authority (PoA)	Similar to PoS and DPoS. Blocks are only created when a consensus is reached among the validators. In this network there is something of a decentralization where the validators are pre-selected.	+	Public, private or consortium	probabilistic	ovan, Rinkeby, Giveth, TomoChain, Rublix, Swarm City, Colony, Go Chain.
Proof of Burn (PoB)	Coins owned by a node and obtained from a previous protocol such as Bitcoin are burned to gain the privileges of creating new blocks in that network.	o	public	Immediate	Slimcoin and Counterparty
Proof of Capacity (PoC) or Proof of Space (PoS)	It is the closest to PoW with differences. Instead of making the effort to check, each block the effort is made in advance and is called plotting. The results are used to verify the future block.	++	public	probabilistic	Burstcoin and Bitcoin Ore
Proof-of-Stake-Time (PoST)	The longer a node is in the network, the more probable to participate in the block mining	+	public	probabilistic	VeriCoin Blockchain Explorer
Proof-of-Brain (PoB)	This protocol enables intelligent people to enter the network through their valuable social participation		public	probabilistic	Steemit
Proof-of-Physical-Address (PoPA)/ Proof-of-Bank-Account (PoBA)	Rely Blockchain with the physical address	+	Private	Immediate	ConsenSys and POA Network
Proof-of-concept (PoC)	It is a copy of the concept of proof of concept in Blockchain. An example is the feasibility of check of insured vehicles.	o	Private	Immediate	Shared KYC Platform, FinTech
Our proposed framework	The protocol enables adding block based on the reputation of node	++	Semi-public	Immediate for master node/probabilistic for new nods	-

IV. Proposed Framework

A level of trust among parties is necessary for most forms of transactions. However, if an immutable ledger of data existed, we could remove this dependency on others. A Blockchain-based news consortium aims to do just that by using a decentralized network. With no central authority, it is exceedingly hard to alter the data inside a ledger. An agency would have to control over half of the platform to create a consensus. This fundamental principle leads to a secure system. As a result, certain industries are moving their processes over to this new technology, particularly those that require a greater degree of trust. Now we briefly present core functionalities of our proposed framework including fake news detection technique, node accreditation process, and news verification scenarios to illustrate the working of our proposed framework.

A. Detection Framework

Blockchain is a decentralized system in which there is a requirement of consensus between nodes to perform a secure transaction. We classify nodes as Master or untrusted nodes in our proposed customized blockchain network as shown in Fig. 1. Master nodes are selected based on their good past reputation. We suggest that the news issuance and verification process starts from Master Nodes in the private network of the Blockchain, and each node has its own contracts and database that contains the correct news. The master node is reliable nodes, such as the nodes in Twitter, which have a blue checkmark, or like Facebook.

For the news that is not issued from a reliable node, such as P1, P2, or P3, an automatic and intelligent mechanism will apply to verify the validity of the news. On the other hand, each node of the Blockchain contains complete information, so searching for it will be somewhat slow, especially in the case of many blocks in the chain. Therefore, we propose to develop a news indexing process through keywords that are stored in the nodes themselves, which will facilitate and speed up the verification process.

This research proposes an improved framework that integrates Blockchain and text-mining algorithms. Our proposed mechanism will verify the validity of the news received or the Islamic Fatwa from the Semi-Trust environment. For the proof of concept, we presented two scenarios for our proposed framework (Fig. 1).

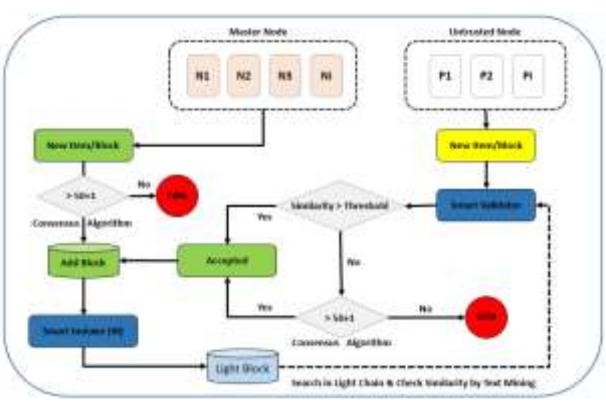

Fig. 1. Proposed Framework – S2.

The list of trusted nodes is formed by the rate of participation of the node in verifying the news and its authenticity as trusted news. In case the news is verified is authentic then the verifying node gets a score of +1 and a score of -1 is assign in case of wrongly verifying news. After reaching the desired score, the node is upgraded as the master node and gains a higher power to vote and verify the news.

A group of unreliable public contracts representing individuals or entities that are not accredited. Here we will have different scenarios to work according to the nature of the system and the level of sensitivity of the information as well as the type of node created for the news. We will discuss all these scenarios in the following paragraphs.

For adding a new block, the voting is done by the trusted nodes in the proposed model as shown in Fig. 2. A new block consists of the contents of the block's header. Then the proposed TM algorithm finds the keywords from the news text and stores them instead of the whole text to reduce the size significantly by more than 80%.

The voting process will take place in the first stage through the TM algorithm to measure the degree of similarity with other reliable news, and this will be completely automated. The transition to the traditional voting model is carried out so that each node (as an editor of the news) votes on the news through manual verification (here only trusted nodes) in the event that the achieved percentage is not higher than the threshold. This threshold will be determined based on experience and testing, which can be adapted to the nature of the news, for example, technical, sports, political.

B. News Verification Scenarios

1) Scenario 1 - A trusted node added a news (Algorithm 2): When a trusted node adds news, there is no need for voting or get a consensus on the news. A new block will be created that contains in its header the hash code of the previous node, as well as the date of its creation, block creator, a random number, and the news itself. This is all to ensure that it is connected to the previous block in the chain, and to ensure that its content is not modified.

At the same time, important keywords will be found in the news via the algorithm (3) based on the principles of information retrieval algorithms and the processing of natural texts. A parallel series of news will then be updated, but with much less information. Therefore, we called it a light chain.

Header	- Hash of previous block (HA_P) - Time Stamp (DT) - Owner Name (N1) - Nonce (n) Unique Random Value - Hash (Data + HA_P + N1 + DT + n) - Number of Block (ID) (Last ID+1)
Content	Text Data
Signature	Encryption of (Hash) by Public Key of N1

Fig. 2. Block Format in our System with Text News.

The importance of previous light chain and index steps will be illustrated in the following untrusted contract scenarios. Importantly Blockchain is used in the process to ensure that the data is not modified and saved in a multi-copy version of all trusted contracts, for future verification. However, accepting the news directly by the trusted node and canceling the consensus process will be linked to the sensitivity of the information or application. Therefore, a constraint in the consensus process is added before the news or information is added to the blockchain. For example, a consensus score of 10% of a trusted contract can be accepted as an alternative to the 50+1 score used in public chains. So here, we have reduced the load and accelerated the performance by overcoming some unnecessary steps.

Algorithm 1 : Trusted_node_Validation method

```
Input: Node N, Message Msg
Output: Accept/ reject, Update (Lightweight.Chain, CA.Index)
Begin
        Accept (Msg)
        Nonce ← Generate_Random_ID()
        P_Hash← Get_Hash_of_Last_Block_in_the Chain()
        N_Hash←Hash_Function(Msg, N, Date, P_Hash, Nonce)
        Header ← New Header (N, Date, Nonce, N_Hash)
        NBlock←Create_New_Block( Header, Msg)
        Broadcast ( List_of_Trusted_Block[], NBlock )
        K ← Find.Keywords ( Msg ) // Details of this function will explain later
        Update( Lightweight.Chain(K) )
        Update ( CA.Index (K) )
End
```

2) Scenario 2 - An untrusted node added a news (Algorithm 3): In case that the news is coming from a member of un-trusted nodes, then an intelligent principle is applied to verify the consensus through three successive phases of verification. It stops when a threshold is achieved.

Phase one:

A proposed similarity measurement algorithm (Algorithm 4) will be used to verify the node. This algorithm will search within the Certified Authority (CA) example master node index to find block numbers that contain similar content in the series. Then the search will be in the light chain within only the specified block numbers, and the proposed similarity algorithm (Algorithm 4) will be used to measure the similarity ratio with each block, and if a similarity is found greater than a threshold, it is considered as a positive vote for the new block. Similarly, one or more votes are required depending on the nature of the application. It is also possible to check more than one series (i.e. at more than one reliable node) to check for the presence of a fake or hacked chain.

Phase two:

If no similarity is found with a previous block, at this stage the similarity algorithm will be applied to all unsupported blocks that have been submitted by the untrusted nodes. If the similarity ratio with a certain number of nodes is greater than the specified threshold, the new block will be trusted.

Phase three:

If the verification is not achieved in the previous phase, then the third phase is initiated, which is the traditional vote request from the trusted nodes. The news is accepted only if it is voted (approved) by a certain number of trusted nodes, for example, 10%, or the traditional principle of Blockchain can be relied upon and a vote of 50+1 of all nodes.

Here, the reputation of the nodes that participated must then be modified based on the comparison between the type of voting and the final result of the block.

Algorithm 2 : UnTrusted_node_Validation method

```
Input: Node N, Message Msg
Output: Accept/ reject, Update (Lightweight.Chain, CA.Index)
Begin
        Consensus ← 0
        Block_IDs[] ←Search_in_CA_Index(Find.Keywords(Msg))
        Msgs[] ← Get_Light_Block (Block_IDs[])
        foreach Msg~ in Msgs do
                Sim ← Check_Similarity ( Msg~, Msg )
                If Sim > Threshold2 Then
                Consensus ← Consensus+1
                end if
        end for
        if Consensus > Threshold2 then
         Accept ( Msg )
                Nonce ← Generate_Random_ID()
         P_Hash ← Get_Hash_of_Last_Block_in_Chain()
                N_Hash ← Hash_Function(Msg, N, Date, P_Hash, Nonce)
                Header ← New Header(N, Date, Nonce, N_Hash)
                NBlock ← Create_New_Block( Header, Msg)
                Broadcast ( List_of_Trusted_Block[], NBlock )
                K ← Find.Keywords ( Msg )
                Update ( Lightweight.Chain(K) )
                Update ( CA.Index (K) )
        else
                foreach Msg~ in Un_confirmed_Msgs
                        Sim ← Check_Similarity ( Msg~, Msg )
                        if Sim > Threshold1 then
                                Consensus ← Consensus+1
         end for
                if Consensus > Threshold2 then
                Accept ( Msg )
                Nonce ← Generate_Random_ID()
         P_Hash← Get_Hash_of_Last_Block_in_Chain()
                N_Hash←Hash_Function(Msg, N, Date, P_Hash, Nonce)
                Header ← New Header(N, Date, Nonce, N_Hash)
                NBlock←Create_New_Block( Header, Msg)
                Broadcast ( List_of_Trusted_Block[], NBlock )
                K ← Find.Keywords ( Msg )
                Update ( Lightweight.Chain(K) )
                Update ( CA.Index (K) )
                else
                        Consensus ← Traditional_Consensus( Msg )
                        if Consensus > Threshold2 then
                                Accept ( Msg )
                        else
                                Reject (Msg )
          end if
                end if
        end if
End algorithm
```

Extracting keywords from a message:

Algorithm 3 : Find Keywords (Msg) method // extracting keywords from a message

```
Input : message
Output : keywords
Begin
CMsg ← Clean_Text (Msg) // Replace Special Characters by " " by using Replace function or Regex
NMsg ← Normalize ( CMsg ) // Convert all characters to small letters by using convtolower
Terms [] ← Tokenizing ( NMsg ) // Convert sentences to vector of terms by using Split (" ")
Terms [] ← Removing_StopWords (Terms[], English_Stopwords_List)

// Removing un important terms as " the a an in on they I he … "
foreach term in Terms[]
        if English_Stopwords_List.Contain(term) then
            Terms.Remove (Term)
            Terms [] ← Porter_Stemmer ( Terms [] )
            HashTable HTerms ← Find_Freq ( Terms )
        end if
end for
foreach term in Terms
        if HTems.Has (term) then HTerms[term] ←+1
            else HTerms[term] ← +1
        end if
end for
// Find weight | importance of each term by using IF-IDF
WTerms ←Calculate_IDF (HTerms)
foreach term in HTerm
        W ← ((Freq_Term_in_Doc) / (Max Freq in Doc)) * Log (Num of Docs have Term / Num of Docs)
        RTerms ← Remove_unimportant_term ( WTerms, Threshold )

// Remove who importance less than Threshold
foreach term in RTerms
        if term.W < Threshold then RTerms.Remove(term)
        end if
end for
foreach Term in RTerms
        Keywords [] ← New Keyword ( Term, Freq_in_Doc )
end for
return Keywords[]
```

The algorithm 4 calculates the similarity ratio between two messages. We relied on WordNet [1] anthropology to calculate the similarity between two messages by calculating the distance to their nearest root within the WordNet dictionary tree.

Algorithm 4 : Find Similarity between two terms

```
Input : list of message
Output : the percentage of similarity

Max ←0
Result ← 0
Keywords ← Find_Keywords (Msg)
Keywords~ ← Find_Keywords (~Msg)
for Key1 in Keywords
        for Key2 in Keywords~
                Sim ← Calculate_Similarity ( Key1, Key2)
                if Sim > Max then Max ← Sim end if
        end for
        Result ← Result + Max
        Max ← 0
end for
return Result.
```

To sum up, all algorithms integrate with each other to complete the news verification process. The traditional first voting algorithm of the master nodes is to accept a piece of news, and at the end of the algorithm, the fourth algorithm is invoked to form the modified light chain. Here, those who vote incorrectly will lose a point of reputation credit. After a while, if it continues, they will return as a normal node. In order to verify a piece of news, the fifth algorithm is used by measuring the percentage of similarity. As the participant wins a point in reputation and in the future he may become a master node.

V. Result and Discussion

To test our proposed algorithms, we divide the testing process in five main stages:

- Testing the algorithm that finds the most important words in each news to form the Lightweight chain.
- Testing the Similarity Algorithm to determine the percentage of similarity in the news.
- For the BlockChain, we built our own software to prove the applicability of the proposed model. A new block is generated and a chain is formed. We also tested the modification process on a block in addition to the modification process on one of the chains (that is, the news of the basic operations included in any BlockChain platform).
- Finally, we evaluate the performance of the proposed protocol according to the traditional consensus algorithm in the BlockChain (Table I).
- Our proposal was tested on the Ethereum environment, in addition to an online BlockChain simulator [28] and distributed to users.

A. First - an Algorithm to Discover Important Words

We implemented the proposed algorithm using Visual Studio .NET platform and tested it on a sample of news selected from Twitter as experiential dataset by using TF-IDF as a criterion for importance, which is used in most search engines. Then we tested 12 queries (12 new news items) and based on the number of important words returned from each query, the values TP, TN, FN, FP were calculated according to their respective equations 1,2 & 3. Finally, the main criteria to measure accuracy is calculated such as Accuracy, Precision, and F1-Score. The results show reasonably high percentage of all four criteria of accuracy in Fig. 3, with an average accuracy of approximately 91%. However, these results are from a small sample and in future we will optimize our algorithm to works with huge datasets with higher accuracy.

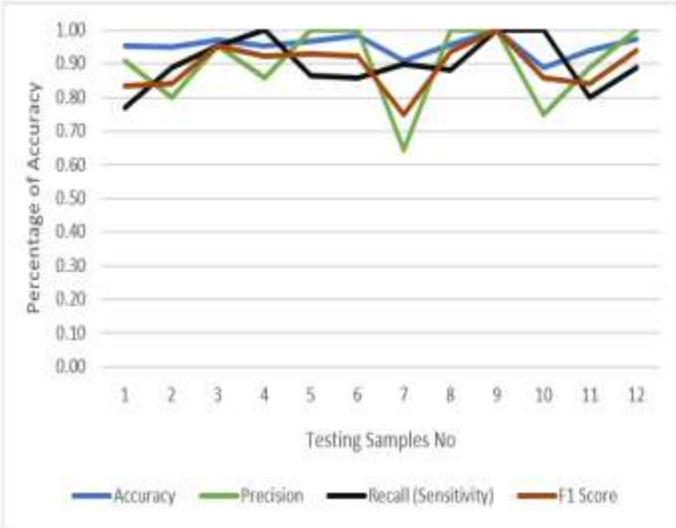

Fig. 3. Features of Proposed Algorithm.

	TP	FP
	FN	TN

$$Accuracy = \frac{TP + TN}{All} \quad (1)$$

$$Precision = \frac{TP}{TP+FP} \quad (2)$$

$$Recall = \frac{TP}{TP + FN} \quad (3)$$

- TP denotes that the two texts are alike and the result is correct.
- TN denotes that the two texts are not the same and the result is correct.
- FP denotes that the two texts are the same but the result is wrong (here the traditional consensus algorithm will be applied and the error effect will be less than the following case).
- IFN: Indicates that the two texts are not the same, but the result is wrong. That is, the information will be accepted without the need for consensus, and this is a state of great danger.

B. Second - Similarity Measurement Algorithm

Initially the algorithm was programmed using Visual Studio .NET, and then we tested it on a group of news articles, chosen from various topics from the BBC platform. Then we calculated the similarity ratio on each pair of articles using the proposed algorithm, and then compared the result with the average results that were measured by three similarity ratio arbitrators.

Finally, we estimate the MSE (mean square error) using equation (4) [16], where its value is 6.9. This low value of MSE represents very good accuracy of the proposed algorithm. The results of the comparison are shown in Fig. 4. The average of Manual similarity is calculated based of the result of similarity of real news against news widespread on some social media sites. A group of linguistic expert does this calculation.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}[(y_i - \hat{y}_i)^2] \quad (4)$$

C. Three - BlockChain

The Visual Studio.Net platform was also used to build our own simulator to achieve the basic operations in the BlockChain: creating a new block and adding it to a chain, in addition to testing a modification process on a specific block at the end or middle of the chain. Finally, the process of synchronization is between several chains.

Fig. 5 shows our simulator. The main goal of using the simulator with the previous two algorithms is to ensure the testing of the complete proposed platform because it is difficult to modify the workings of existing BlockChain platforms. Also, in this research, we proposed a different method of management compatible with the new and proposed use in verifying the validity of news. This all makes it difficult to compare the proposed platform with another existing platform, due to the different purposes of the application and the mechanism of work.

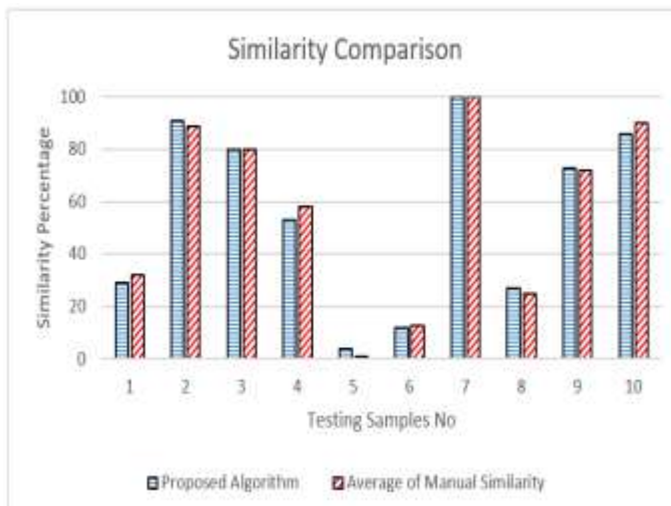

Fig. 4. Comparison of Similarity Check.

Fig. 5. Error appeared in Block 3 and the following after Modifying the Data in this Block during the Test.

Finally, in order to integrate all the ideas together (Blockchain with similarity algorithm) we built our own simulator for all Block-Chain functions (where a formed block containing: a unique number, a random number, the date of construction, the hash code of the previous block, in addition to the hash code of the block itself). When a block is added, the similarity algorithm will be applied, and in case of an acceptable similarity percentage, it will be added in green directly; otherwise, normal voting will take place.

We used SH1 as a Hashing algorithm; we built the chain and giving the power to modify a particular block for experimentation purposes (Fig. 6). Just modifying any block from the chain will be re-evaluated, the modified block color will change, and thus all the block that follows in the chain. Therefore, this chain at a certain node will be different from the rest of the chain, and any new block that sends from this node will be rejected immediately because the hash code will be different from the rest when calculated for the verification process.

For the Blockchain, several methods have been adopted to implement the proposed system and emphasize its effectiveness and the possibility of its implementation. Initially, we used a ready platform like Ethereum to build the system. But we faced difficulty in adjusting the consensus algorithm (Fig. 6 and 7). Therefore, the second solution of the simulation platform [28] is used to clarify the form of a chain in the proposed system. In addition, the solution shows the advantages of using Block-Chain use in terms of ensuring Non- Repudiation, with the error detected immediately and spread to all elements of the following chains in case of a modification in any previous adopted news [30].

D. Fourth - Discussing the Performance of the Proposed Model

We point out that the proposed algorithm will achieve a tangible improvement in performance, but that is conditional on the nature of the use as well (for example, verifying the validity of news) in which the similarity ratio can be assessed. This means that the news in which there may be repetition or similarity in the contents of its blocks, but with a different wording.

Here the proposed method can provide a verification mechanism instead of the traditional consensus mechanism, which can be hacked with a 50+1 attack, although current platforms have tried to solve this attack by switching to establish consensus based on proof of good past history. However, it must be noted that it is only suitable for certain text-based applications.

Performance cannot be truly assessed until we fully apply the platform to real data with large numbers of users. Nevertheless, the similarity checking process is a new test factor that limits the effects of the previous attack and saving time in the event of immediate adoption of the news.

However, if the news is completely new, this will affect the performance somewhat for the worse, as the time will be (T1 + T2). Where T1 represents the time taken to apply the similarity algorithm, and T2 represents the time required for the consensus algorithm. Hence, the performance of the proposed model will be as follows

$$performance = T_1 * R + T_2 * (1 - R)) \quad (4)$$

where, R is the rate of finding the proof based on similarity.

If T1<T2 is taken for granted due to the dependence on only part of the chain (trusted users) then it can be said that performance will be better when R>0.5.

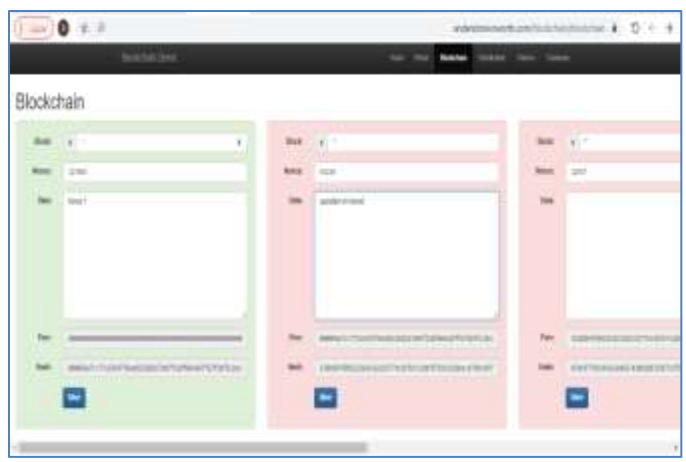

Fig. 6. How the Error Spreads once the Data is Modified.

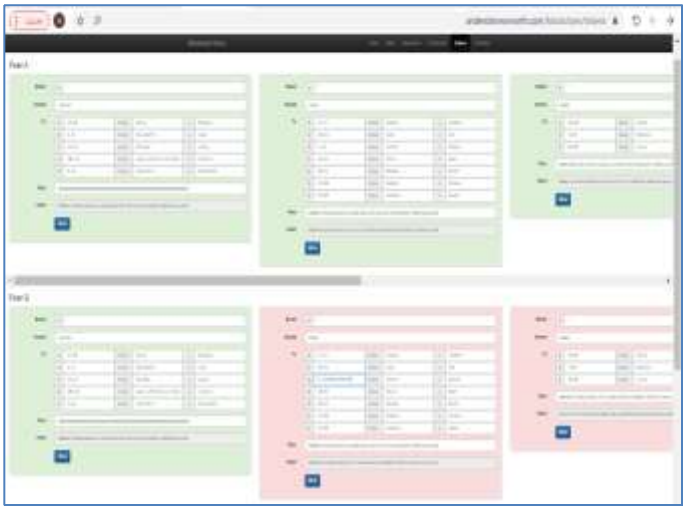

Fig. 7. An Example of more than One Peer of How One of Them has a different Block.

VI. Conclusion

Preventing the dissemination of fake news on various online platforms is one of the major research challenges for the research community. Considering the importance of detecting fake news to stop its dissimilation, we propose a blockchain-based platform to detect fake news. We slightly customize the structure of BlockChain to form a lightweight chain. Then establishes the process including algorithm and technical details to detect fake news. Text mining plays an important role to determine the authenticity of the tested news and its similarity index with existing news. Testing results of the basic simulation scenarios suggests the effectiveness of the proposed solution as a proof of concept. However, in the future, we are planning to perform comprehensive testing in various scenarios. We also plan to test the proposed solution for other similar applications such as verifying the authenticity of published religious rulings (fatwas).

Also, through this research, we started by launching a small initiative of a new consensus algorithm that will be based on the reputation of the participating nodes. This algorithm will be developed and all necessary tests will be performed to become a new consensus algorithm. This last will be effective in such type of applications.

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Auditor's Perception on Technology Transformation: Blockchain and CAATs on Audit Quality in Indonesia

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***Abstract*—The purpose of this study is to analyze the auditor's perception of the implementation of technology transformation such as: blockchain and CAATs that can affect audit quality at the Big Four Public Accounting Firm in Jakarta. This study uses quantitative research methods using a combination of primary and secondary data. The data collection techniques used in this study was questionnaires. The sample was taken using purposive sampling method, which resulted in 60 respondents. Data analysis was carried out with SmartPLS 3.0 and IBM SPSS 26 software which resulted in the conclusion that the auditor's perception of the implementation of blockchain had a significant positive effect on audit quality, while the auditor's perception of the implementation of CAATs had no significant positive effect on audit quality.**

Keywords—Blockchain; CAATs; audit quality; auditor's perception; technology transformation

I. Introduction

The technological revolution and new business models emphasize the rapid use of technology. Technology has changed audit data processing and data storage from manual to automated. The role of auditors is increasingly important when digitalization in business processes is increasingly dominant [8]. The development of information technology in the company is not in line with changes in information technology-based auditing practices. This statement is supported by a World Bank report which states that auditors in Indonesia tend to use simple procedures to detect fraud and provide opinions on "going concern" assumptions. In this case, there is no rigorous process and it is a challenge to provide an accurate audit opinion as stakeholders feel they do not have sufficient information. This leads to questionable audit quality. To address audit quality issues, it is necessary to apply best audit practices by leveraging technological transformations in the audit process such as the use of blockchain and CAATs. The facts on the ground show that there are many problems related to audit quality, such as: SNP Finance, PT Hanson International Tbk, Indosat Ooredo, Garuda Indonesia, PT KAI (Indonesian Railways).

KAP really needs to solve the problem of high audit fees, low efficiency and high audit risk. It seems that blockchain is becoming the next step in the digital era and is expected to have an impact on business and society and attract the attention of scholars and practitioners [16]. In addition to blockchain, CAATs are one of the technological transformations in the field of auditing. CAATs can support auditors in collecting big data as audit evidence and analyzing it in a single database. The more data that is used as evidence, the less likely there is to be fraud or fraud. Although the cost of implementing CAATs is high, it reduces the work cost of the company's entire audit activity by increasing productivity and reducing the number of errors in the audit process. CAATs can help auditors provide the best service for their clients [15, 22]. New discoveries such as big data and other similar technological advances have greatly increased the opportunities to improve current audit quality and practice. Due to audit limitations and lack of time, the auditor is forced to choose a smaller sample size, which can also lead to possible risk assessment and inadequate audit procedures. The contribution of this research is to determine audit quality through auditors' perceptions of technological transformation in the form of Blockchain and CAATs in public accounting firms in Indonesia.

II. Theoretical Framework

A. Agency Theory

High audit quality can improve the quality of financial reports and support wise investment decisions and financial stability, but can also be used as a monitoring mechanism to reduce asymmetric information between managers and shareholders [5, 20]. Audit quality can help companies obtain credit from the most prestigious creditors and attract potential investors to invest [17, 21]. Audit quality plays an important role in increasing public confidence in the capital market by providing better information and confidence in the reliability and accountability of financial reports reported by management.

Agency theory can be defined as the relationship between the owner (principal) and management (agent), where the principal authorizes the agent to manage the company. If the principal and agent have the same goal, the agent will act in accordance with the wishes of the principal, agency problems arise when there are differences in the objectives of the principal and agent which gives rise to asymmetric information which is the difference in information between the principal and the agent, where the agent has more and more information than the principal because the agent spends more time in the company than the principal. The existence of asymmetric information can open up opportunities for agents to take inappropriate actions, which can harm the principal or the company by using company assets for personal gain. The task of the auditor is to provide services to assess the financial statements made by the agent regarding the fairness of the financial statements, so that the auditor is considered an independent party who can help overcome agency problems. In assessing the company's financial statements, the auditor must carry out the audit process optimally to obtain good audit quality.

Blockchain makes audit work easier but still has some problems to solve. To maintain audit quality, auditors must consider and assess blockchain risks in audits, such as: ID theft, illegal activity, and system hacking [9]. Information technology, audit techniques, and time budget pressure have a positive (+) effect on audit quality [13]. Private blockchains are attractive because they offer better audit solutions, automated controls, data reliability, reduced audit fees and less human error, avoids manipulation and fraud, improves information integrity, but blockchain still needs a lot of development, such as design, flexibility, and cyber security [3]. CAATs have a positive (+) effect on IT Audits [2]. In the research, Cheng and Huang (2020) also did not have variables in their research with results showing that blockchain has enormous potential in auditing and accounting. Although research on blockchain auditing is still in its infancy, blockchain technology can very well solve the problems currently facing the audit industry. [4].

With the help of blockchain audits, large-scale and real-time automated audits can be implemented. While companies can improve their data security structures, regulators are expected to strengthen and enforce crime-related regulations [37}. Blockchain had an effect on the audit process and auditors, especially in collecting evidence and conducting audits [18]. CAATs increase audit effectiveness and efficiency but CAATs need deeper study and auditors' consideration because it is difficult to master CAATs. Middle to lower KAPs are still not interested in using complex CAATs [15]. Auditors see a high performance expectancy from the use of CAATs [11]. Auditor independence, auditor experience, and application of Audit Techniques Computer Assisted has a positive (+) effect on the effectiveness of the investigative audit in detecting fraud [7]. Blockchain is able to improve financial reporting and audit processes because auditors can access data in real-time, obtain information in a consistent and repeatable format, obtain audit evidence directly and according to procedures and overcome risks, audit but still have to do a professional analysis [16].

III. Hypothesis Development

A. *Effect of Blockchain Implementation on Audit Quality*

Blockchain is a technology for recording, processing and storing financial transactions [10, 22]. Blockchain records transactions chronologically with the cryptographic hash referring to the hash of the previous block, when any changes are made, all other copies are updated at the same time so that if there is fraud it will be easier for auditors to detect. After reaching consensus, all nodes can access the same information, and a distributed global view of the chain ensures the availability of stored information so that there is high transparency, auditors can access all required transactions and can obtain sufficient and reliable evidence to determine whether there is a material misstatement. Blockchain implementation allows auditors to focus on data analysis and decision making rather than checking recurring transactions and ensuring that they meet accounting standards [4]. Blockchain can reduce audit fees, human error, and fraud [3]. Blockchain helps the audit process, especially in the collection of reliable and transparent audit evidence [18]. Blockchain implements a real-time system and large-scale automated audits, as well as guaranteed data security [19]. The hypotheses in this study are as follows.

H1: Blockchain implementation has a positive effect on audit quality.

Effect of CAATs Implementation on Audit Quality

CAATs are computerized programs to carry out audit functions so as to facilitate the audit process and also facilitate access and perform comprehensive operations on various types of electronic data so that fraud can be prevented early [2] thus affecting the quality of audits produced by auditors. Public accounting firms use software to help auditors complete their audit tasks with the help of computers so that auditors can carry out their duties properly and produce high-quality audit reports. Implementation of CAATs and training to understand the use of CAATs tends to be expensive because auditors who will use CAATs need to have knowledge depending on the complexity of CAATs so there are considerations from several KAPs. CAATs have a positive (+) effect on the operational review of IT audits which consist of preaudit, implementation, and reporting [2]. Computer Assisted Audit Techniques [1], Auditor Competence, Independence, and Work Experience have a positive (+) effect on audit quality [12]. CAATs increase audit effectiveness and efficiency but are difficult to implement, so there are still considerations from KAP [15]. The hypotheses in this study are as follows:

H2: The application of CAATs has a positive effect on audit quality.

IV. Research Methodology

This research was conducted by focusing on the Big Four KAP operating in Jakarta, Indonesia. The sample in this study were auditors at KAP Big Four Jakarta. Indonesia who have knowledge related to research topics and are interested in participating in this research. In this study, the author uses quantitative research methods, which can be interpreted as research that uses data in the form of numbers from calculations and measurements that are processed and analyzed with certain statistical criteria. Quantitative research is more likely to be used to prove phenomena (hypotheses) [12, 21].

In this study, information was collected from respondents using a questionnaire. Due to the large population, the authors collect data using a sampling technique, namely purposive sampling. The results of the selected sample will represent the entire population. The number of population is unknown, so the Roscoe formula is used, namely the sample size in multiple regression analysis is at least 10x larger than the number of variables in the study and must be more than 30 and less than 500 samples [6]. The sample was selected using the following criteria: Auditor has worked at KAP Big Four for at least 1 year; Auditors have knowledge and understanding of blockchain, CAATs, and audit quality; Auditors have an interest in participating in research.

The sample members are selected based on criteria, such as people who already have proven knowledge, experience, and skills in the field being researched. The number of samples used as respondents as many as 60 samples. The results of data analysis in this study consisted of respondent characteristics, descriptive statistical analysis, normality test, multicollinearity test, heteroscedasticity test, autocorrelation test, validity test, and reliability test; the results of hypothesis testing consisting of the coefficient of determination (R^2), f-square (effect size), path coefficient, T-Statistics test (bootstrapping), predictive relevance (Q2), and model fit; discussion of research results [14, 20].

Operational variable

Blockchain Application (X1) measured by indicator: (1) knowledge and skills of auditors related to blockchain; (2) Availability of support for blockchain implementation in the audit process; (3) Effectiveness in implementing blockchain; (4) Efficiency in blockchain implementation. Application of CAATs (X2) by using indicators; (1) Knowledge and skills of auditors related to CAATs; (2) Effectiveness in implementing CAATs.(3). Efficiency in the application of CAATs. Audit Quality (Y) with indicator measurement: (1) Professional knowledge, expertise and experience; (2) Misstatement detection; (3) Compliance with auditing standards; (4) Quality of audit report.

V. RESULT AND DISCUSSION

A. Descriptive Statistical Analysis

The Table I shows descriptive statistical analysis of the mean value of Exogenous Variables (Blockchain Application) of 38.90; the mean value of Exogenous Variables (Application of CAATs) is 41.25; the mean value of Endogenous Variables (Audit Quality) is 63.68. The standard deviation value for Exogenous Variables (Blockchain Application) is 6.501; the standard deviation value of Exogenous Variables (Application of CAATs) is 6.022; the standard deviation value of Endogenous Variables (Audit Quality) is 4,489.

TABLE I. DESCRIPTIVE STATISTICAL ANALYSIS

Variable	**Mean**	**Standard Deviation**
Exogenous (Blockchain Implementation)	38,90	6,501
Exogenous (Application of CAATs)	41,25	6,022
Endogenous (Quality Audit)	63,68	4,489

Source: Processed data (2021)

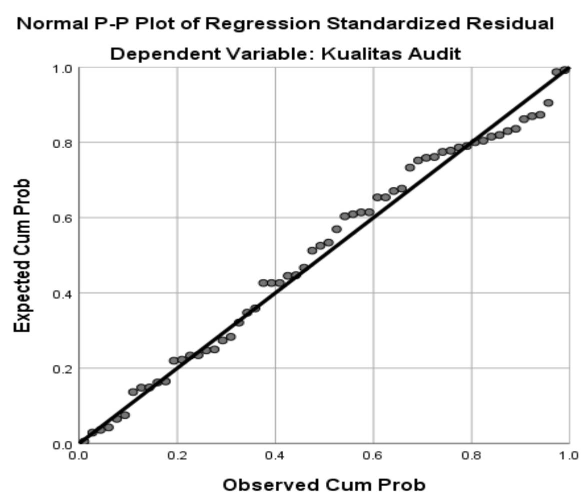
B. Normality Test

The absolute value is the statistical value of the Kolmogorov-Smirnov test, while the significance value of Asymp. Sig. (2-tailed) is the probability value of the Kolmogorov-Smirnov test. By using 60 samples and a significance level of 0.05, the Kolmogorov-Smirnov critical value is 0.172. Judging from the Table II, the absolute value is 0.073 <0.172 and the Asymp value. Sig. (2-tailed) of 0.20 > 0.05. So, the data in this study are normally distributed.

TABLE II. NORMALITY TEST

One-Sample Kolmogorov-Smirnov Test		
		Unstandardized Residual
N		60
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	4.01092676
Most Extreme Differences	Absolute	.073
	Positive	.073
	Negative	-.072
Test Statistic		.073
Asymp. Sig. (2-tailed)		.200[c,d]
a. Test distribution is Normal.		
b. Calculated from data.		
c. Lilliefors Significance Correction.		
d. This is a lower bound of the true significance.		

Source: IBM SPSS 26 output, processed data (2021)



Source: IBM SPSS 26 output, processed data (2021).

Fig. 1. Probability Plot Normality Test.

Seen in the Fig. 1, the dots spread around the diagonal line and follow the diagonal line. This shows that the data is normally distributed. The P-P Plot of Regression Normal Test can be done if you are still unsure of the Kolmogorov-Smirnov test results.

C. Multi-collinearity Test

Based on the Table III, it can be seen that the value of Exogenous Variables (Blockchain Application) and Exogenous Variables (CAATs Application) value is the same, namely 1.208 which means that the two exogenous variables in this study have a VIF value < 10. This means that there is no multi-collinearity in this study.

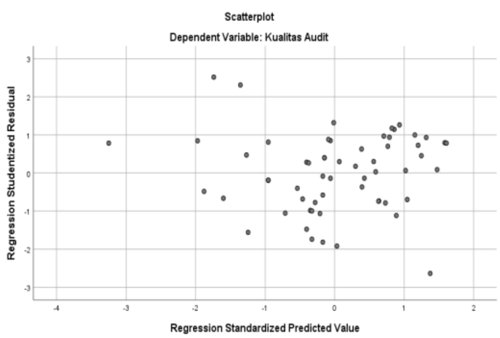
TABLE III. MULTI-COLLINEARITY TEST

	VIF	Information
Exogenous Variables (Blockchain Implementation)	1,208	There is no multi-collinearity
Exogenous Variables (Application of CAATs)	1,208	There is no multi-collinearity

Source: Output SmartPLS 3.3.3, Data processed (2021)

D. Heteroscedasticity Test

The Park test was carried out by looking at the scatterplot using SRESID as the Y variable and ZPRED as the X variable. It can be seen from the Fig. 2 below that there is a random distribution of points in the residual analysis around 0, the spread the points are far from the X and Y axes. So, it can be concluded that there is no heteroscedasticity.



Sumber : Output IBM SPSS 26, Data diolah (2021).

Fig. 2. Heteroscedasticity Test.

E. Autocorrelation Test

The Table IV shows Durbin Watson's result of 2,061. By using 60 samples, obtained a dL value of 1.5144 and a dU value of 1.6518 from the Durbin Watson table. If 1.65 < d < 2.35, it means that there is no autocorrelation, if 1.51 < d < 1.65 or 2.35 < d < 2.49, it means that it cannot be concluded, if d < 1.51 or d > 2.49 means that there is an autocorrelation. Judging from the statement obtained the results: 1.65 < 2.06 < 2.35, it can be concluded that there is no autocorrelation in this study.

TABLE IV. AUTOCORRELATION TEST

n	Durbin Watson	dL	dU	4-dL	4-dU
60	2,061	1,5144	1,6518	2,4856	2,3482

Source: IBM SPSS 26 output, processed data (2021)

F. Validity Test

The following measurement model is used to analyze the questionnaire:

Based on the Fig. 3 of the loading factor analysis of SmartPLS 3.3.3, it can be seen that many indicators have a value below 0.6, namely: BC2 with a value of 0.427; BC3 with a value of 0.360; BC4 with a value of 0.387; CA2 with a value of 0.583; KA1 with a value of 0.576; KA2 with a value of 0.515; KA3 with a value of 0.478; KA4 with a value of 0.401; KA5 with a value of 0.525; KA6 with a value of 0.591; KA7 with a value of 0.503; KA8 with a value of 0.565; KA10 with a value of 0.592; and KA14 with a value of 0.550. Indicators with values below 0.6 are invalid and must be removed from the model. If the indicator used is not valid then it cannot measure each variable, the value given by the exogenous variable to the endogenous variable cannot be used as a guide.

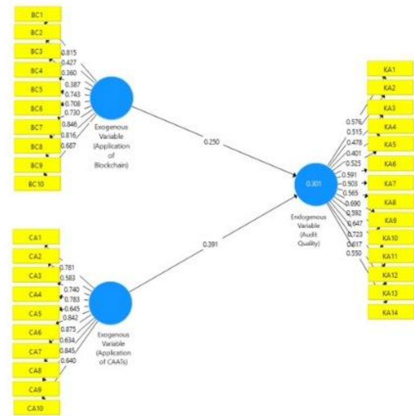


Fig. 3. Estimated Measurement Model.

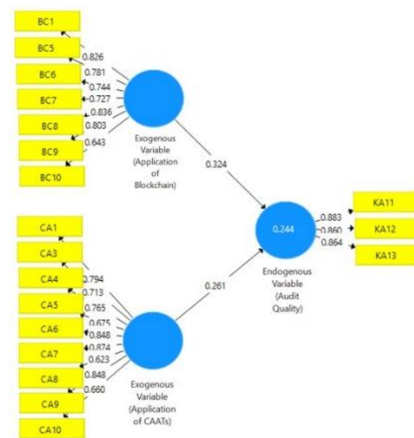


Fig. 4. Valid Model Estimation.

From the model estimation Fig. 4, it can be seen that after all indicators have a loading factor value above 0.6 so that the model meets the requirements of convergent validity. All indicators used are valid, namely: BC1 with a value of 0.826; BC5 with a value of 0.781; BC6 with a value of 0.744; BC7 with a value of 0.727; BC8 with a value of 0.836; BC9 with a value of 0.803; BC10 with a value of 0.643; CA1 with a value of 0.794; CA3 with a value of 0.713; CA4 with a value of 0.765; CA6 with a value of 0.848; CA7 with a value of 0.874; CA8 with a value of 0.623; CA9 with a value of 0.848; CA10 with a value of 0.660; KA11 with a value of 0.883; KA12 with a value of 0.860; and KA13 with a value of 0.864.

1) Convergent validity test: The convergent validity test can be seen by looking at the value of outer loadings in the PLS Algorithm. Each indicator with a value > 0.6 has been declared valid. If there is still a value < 0.6, then you must return to the estimation model and delete indicators that have a value < 0.6. The Table V shows a comparison of the value of outer loadings before being deleted and after being deleted 2 times. After deleting the value at < 0.6, the value of KA9 changed from 0.690 to < 0.6 i.e. 0.537; so it must be deleted again before doing the next test.

TABLE V. OUTER LOADINGS

Indicator	Outer Loadings Before Deletion	Outer Loadings After Deletion
BC1	0,815	0,826
BC2	0,427	-
BC3	0,360	-
BC4	0,387	-
BC5	0,743	0,781
BC6	0,708	0,744
BC7	0,730	0,727
BC8	0,846	0,836
BC9	0,816	0,803
BC10	0,687	0,643
CA1	0,781	0,794
CA2	0,583	-
CA3	0,740	0,713
CA4	0,783	0,765
CA5	0,645	0,675
CA6	0,842	0,848
CA7	0,875	0,874
CA8	0,634	0,623
CA9	0,845	0,848
CA10	0,640	0,660
KA1	0,576	-
KA2	0,515	-
KA3	0,478	-
KA4	0,401	-
KA5	0,525	-
KA6	0,591	-
KA7	0,503	-
KA8	0,565	-
KA9	0,537	-
KA10	0,592	-
KA11	0,647	0,883
KA12	0,723	0,860
KA13	0,617	0,864
KA14	0,550	-

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE VI. AVERAGE VARIANT EXTRACTED (AVE)

Variable	Average Variant Extracted (AVE)	Information
Exogenous (Blockchain Implementation)	0,590	Valid
Exogenous (Application of CAATs)	0,578	Valid
Endogenous (Quality Audit)	0,756	Valid

Source: Output SmartPLS 3.3.3, Data processed (2021)

In addition to using the loading factor, the convergent validity test is also seen from the AVE value from Table VI. The AVE value can be seen by selecting construct reliability and validity. The AVE value is used to ensure that there are still invalid indicators after the loading factor test. An AVE value > 0.5 indicates that the AVE value is valid and an AVE value < 0.5 indicates that there are still invalid indicators. The three variables have a value > 0.5, which means that all variables are valid.

2) Discriminant validity test: Table VII shows the first discriminant validity test is by using the Fornell-Larcker Criterion by looking at the correlation of the variable with the variable itself, it must not be smaller than the variable with other variables. If the correlation of the variable with the variable itself is smaller than the variable with other variables, it must remove the lowest indicator value from that variable because the correlation value generated by loading factors results in a lack of the Fornell-Larcker Criterion test. In this study, the correlation between the variables and the variables themselves is greater than the variables with other variables.

Table VIII shows the second discriminant validity test is by using cross loadings. Cross loadings can be seen by comparing the correlation of indicators with their own variables, whether it is greater than the correlation of indicators with other variables. When there is an indicator correlation with other variables that is greater than the indicator correlation with its own variable, it must be removed. Because everything is valid, both the convergent and discriminant validity tests, the indicators that are owned can be used as a measure of the variables used.

G. Reliability Test

Reliability test using Cronbach's alpha can be seen by selecting construct reliability and validity from Table IX. The value of Cronbach's alpha in this study can be seen in the table above, which means that each variable used is all reliable because the Cronbach's Alpha value of each variable is > 0.6. Same as the previous test, if it displays red, it means it is not reliable.

TABLE VII. FORNELL-LARCKER CRITERION

	Exogenous Variables (Blockchain Implementation)	Exogenous Variables (Application of CAATs)	Endogenous Variables (Audit Quality)
Exogenous Variables (Blockchain Implementation)	0,768		
Exogenous Variables (Application of CAATs)	0,415	0,761	
Endogenous Variables (Audit Quality)	0,433	0,396	0,869

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE VIII. CROSS LOADINGS

	Exogenous Variables (Blockchain Implementation)	Exogenous Variables (Application of CAATs)	Endogenous Variables (Audit Quality)
BC1	0,826	0,372	0,470
BC5	0,781	0,240	0,335
BC6	0,744	0,275	0,209
BC7	0,727	0,392	0,149
BC8	0,836	0,338	0,318
BC9	0,803	0,358	0,413
BC10	0,643	0,278	0,090
CA1	0,372	0,794	0,356
CA3	0,323	0,713	0,313
CA4	0,213	0,765	0,173
CA5	0,323	0,675	0,288
CA6	0,371	0,848	0,310
CA7	0,345	0,874	0,287
CA8	0,298	0,623	0,219
CA9	0,353	0,848	0,367
CA10	0,182	0,660	0,299
KA11	0,445	0,328	0,883
KA12	0,369	0,404	0,860
KA13	0,292	0,287	0,864

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE IX. CRONBACH'S ALPHA

Variable	Cronbach's Alpha	Information
Exogenous (Blockchain Implementation)	0,895	Reliable
Exogenous (Application of CAATs)	0,907	Reliable
Endogenous (Quality Audit)	0,840	Reliable

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE X. COMPOSITE RELIABILITY

Variable	Composite Reliability	Information
Exogenous (Blockchain Implementation)	0,909	Reliable
Exogenous (Application of CAATs)	0,924	Reliable
Endogenous (Quality Audit)	0,903	Reliable

Source: Output SmartPLS 3.3.3, Data processed (2021)

The second reliability test is by using composite reliability which can be seen by selecting construct reliability and validity that can be seen in Table X. The composite reliability value must be > 0.7 to be said to be reliable. It can be seen in the table above that all variables are reliable because the composite reliability value is > 0.7.

H. Hypothesis Testing Results

From Table XI, the value of 0.244 is only for endogenous variables. If used as a percent, the R Square value becomes 24%, which means that only 24% of Exogenous Variables (Audit Quality) are influenced by Endogenous Variables (Blockchain Implementation) and Endogenous Variables (CAATs Application). The remaining 76% is influenced by other variables that are not used in the study.

The value of R Square Adjusted from this research is 22%. R Square Adjusted to overcome the problem of increasing the value of R Square every time there is an additional variable because R Square Adjusted only measures R Square with a significant value. In addition, it can also be used to estimate the value of R Square from the addition of these variables. Because this study only uses 2 exogenous variables, it is enough to use the R Square value. R Square Adjusted value is more recommended for research that uses many exogenous variables/complex model.

From the Table XII, it can be seen that Exogenous Variables (Blockchain Implementation) have a weak influence on Endogenous Variables (Audit Quality) with a value of 0.115 and Exogenous Variables (Implementation of CAATs) also have a weak influence on Endogenous Variables (Audit Quality) with a value of 0.075. The two exogenous variables have a weak influence because the f-Square values are both < 0.15.

Path coefficient value can be seen by selecting the path coefficient. From the Table XIII, it can be seen that Exogenous Variables (Blockchain Implementation) to Endogenous Variables (Audit Quality) have a value of 0.324 and Exogenous Variables (Implementation of CAATs) to Endogenous Variables (Audit Quality) have a value of 0.261. Therefore, the direction of the relationship of Exogenous Variables (Blockchain) to Endogenous Variables (Audit Quality) and Exogenous Variables (CAATs) to Endogenous Variables (Audit Quality) is positive.

TABLE XI. COEFFICIENT OF DETERMINATION (R^2)

	R Square	R Square Adjusted	Model
Endogenous Variables (Audit Quality)	0,244	0,217	Weak

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE XII. F-SQUARE

	f-Square	Information
Exogenous Variables (Blockchain Implementation) → Endogenous Variables (Audit Quality)	0,115	Weak
Exogenous Variables (Application of CAATs) → Endogenous Variables (Audit Quality)	0,075	Weak

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE XIII. PATH COEFFICIENT

Exogenous Variable	Endogenous Variables (Audit Quality)	Relationship Direction
Blockchain Application Application of CAATs	0,324	Positive
	0,261	Positive

Source: Output SmartPLS 3.3.3, Data processed (2021).

The Table XIV shows that Exogenous Variables (Blockchain Application) have a significant effect on Endogenous Variables (Audit Quality) because the T-Statistics value is 2.203 and p value is 0.030, while Exogenous Variables (Application of CAATs) have no significant effect on Endogenous Variables (Audit Quality) because the T-Statistics value is 1.720 and the p value is 0.089.

Predictive relevance can be seen by using blindfolding – Construct Crossvalidated Redundancy. The results of Q2 in the Table XV show that the model used has a good observation value because it is already above 0 which is 0.152.

Model Fit can be seen from the NFI value in Table XVI. In this study, the NFI value is 0.625, which means that the model used in the study is 63% fit.

TABLE XIV. T-STATISTICS TEST

	T-Statistics	P Values	Information
Exogenous Variables (Blockchain Implementation) → Endogenous Variables (Audit Quality)	2,203	0,030	Significant
Exogenous Variables (Application of CAATs) → Endogenous Variables (Audit Quality)	1,720	0,089	Not significant

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE XV. PREDICTIVE RELEVANCE (Q^2)

	Q^2	Information
Endogenous Variables (Audit Quality)	0,152	Has predictive relevance

Source: Output SmartPLS 3.3.3, Data processed (2021)

TABLE XVI. TABLE XVI FIT MODEL

NFI	**0,625**

Source: Output SmartPLS 3.3.3, Data processed (2021)

VI. DISCUSSION

The Effect of Blockchain Implementation is on Audit Quality.

The test results show that the T-Statistics value is 2.203 and the p value is 0.030; path coefficients value of 0.324. These results indicate that the implementation of Blockchain has a significant positive effect on audit quality. That is, the greater the level of Blockchain application in the audit process, the higher the audit quality. So, the first hypothesis, namely the implementation of Blockchain has a positive effect on audit quality, is acceptable.

Blockchain has many benefits that can be felt by auditors and KAP such as: data security; transparency and traceability; reduce fraud and manipulation; and reduce audit fees. Judging from the benefits of blockchain, with the development of blockchain, the intention of auditors to study blockchain, and the intention of KAP to facilitate resources in implementing blockchain in the audit process, blockchain can bring changes to the audit system. With the reduced intention to use blockchain in audits, it can be seen that the use of blockchain has no effect on audit quality.

The Effect of CAATs Implementation is on Audit Quality. The results of data processing show that the T-Statistics value is 1.720 and the p value is 0.089; path coefficients value of 0.261. These results indicate that the application of CAATs has no significant positive effect on audit quality. That is, the more CAATs are applied in the audit process, the more audit quality will not improve. So, the second hypothesis, namely the application of CAATs has a positive effect on audit quality, is rejected. The application of complex CAATs is quite difficult to learn. So without intention and understanding, CAATs cannot be applied and the benefits offered cannot be maximized because CAATs are only part of auditing standards to collect data and evaluate company transactions. Although in the audit process, CAATs can help auditors in the audit process to be more effective and efficient, such as: enabling the processing of thousands of transaction data, being able to check 100% of all transactions from the database, and CAATs being able to detect financial errors and fraud by checking data availability. The advantages of these CAATs can be utilized by auditors in order to improve audit quality only if the auditor has the desire to learn and use CAATs, and requires knowledge, experience, and skills from the auditors in conducting audits because CAATs are only tools. Judging from the results of the distributed questionnaires, it shows that knowledge and understanding related to computers and CAATs are needed by auditors.

VII. CONCLUSION

Conclusion - From the phenomenon, problem formulation, hypothesis development, results and discussion of research, it can be concluded as follows:

1) The application of blockchain in the audit process has a positive effect on audit quality.

2) The application of CAATs has no positive effect on audit quality.

Suggestions - From the results of this study, there are several suggestions, namely:

1) It is expected that auditors can learn and apply blockchain and CAATs in the audit process so as to improve audit quality. Auditors who have knowledge, understanding, and skills related to blockchain and complex CAATs will have more value and increase effectiveness and efficiency in the audit process.

2) It is hoped that the Big Four KAP in Jakarta Indonesia can implement and facilitate auditors in implementing blockchain and complex CAATs in auditing practices so as to improve audit.

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The Effect of using Flipped Learning Strategy on the Academic Achievement of Eighth Grade Students in Jordan

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***Abstract*—This study aimed to reveal the effect of using the flipped learning strategy on the development of achievement and the trend towards it among eighth grade students in the English language subject in the Hashemite Kingdom of Jordan. The sample of the study consisted of a sample of eighth-grade students who study in government schools affiliated with the Directorate of Education in the Northern Mazar District in the Hashemite Kingdom of Jordan, and their number (50) students were distributed into two groups chosen randomly, one of them is a control group, and the number of its students is (25) and the other Experimental and the number of its students (25) students. Where the control group was taught using the usual method, the experimental group was taught using the flipped learning strategy. To achieve the objectives of the study, the researcher used the descriptive approach and the experimental approach (with a quasi-experimental design), and the study tools were: an achievement test and a questionnaire to measure attitude. The study materials also included educational software. The results of the study indicated that there was a statistically significant difference between the average scores of the group of students. The experimental group and the control group in the post application of the attitude scale in favour of the experimental group, and this indicates that the use of the flipped classroom strategy had an impact on developing students' attitudes towards it.In light of this, the researcher recommends several recommendations, most notably taking advantage of the standards and the proposed educational model in the current research in the field of English language learning, as well as the application of multimedia programs in the use of the flipped classroom strategy, to raise the level of students in the basic stage in academic achievement, and to expand the application of e-learning And blended learning to improve students' attitudes towards using the flipped classroom strategy to learn English, holding training courses for teachers on the use of the flipped learning strategy, and employing modern technologies and social networks in the educational process.**

Keywords—Strategy; flipped learning; academic achievement; eighth grade; introduction

I. INTRODUCTION

Educators are aware of the great impact of using technological innovations in the educational process due to the modern technological revolution of the increasing potential of computer, Internet and communicational applications, which were reflected in the educational process in all of its aspects, It also affected the level of student's learning, planning for teaching, educational content, teaching process Implementation and evaluation. Through using technological innovations in education, there are many teaching strategies that rely on the use of modern technology to provide target educational content to students outside the classroom, which make them deeply involved in the educational content in the classroom [5].

This era is considered the era of modernity, in which modern technologies have appeared, such as owning laptops, smartphones and tablets, and the integration of these collectibles in the educational process has become a modern necessity, so developed countries rushed to harness this technology to add excitement and suspense to the various elements of the educational process, such as the curriculum and effective means of communication between the teacher and the learner, taking into account the individual differences and meeting the special needs of each student, and providing the teacher and the learner with what was not available to them in the traditional educational methods before, so several innovative educational strategies and methods have emerged based on employing this diverse technology in the educational process, most notably inverted learning [11].

Inverted learning enhances the use of advanced technology outside the student's academic time, in order to achieve maximum student participation and learning during the traditional classroom, and to increase efficiency in building knowledge, collaborative work and discussion during the lessons. It seeks to reshape the educational process and change the usual role. It also combines face-to-face learning strategies with an internet-based learning strategy [4].

Flipped learning is a type of blended learning that uses technology to transfer lectures outside the classroom, where the idea of reflexing learning is based on reversing the learning tasks between the classroom and the home, This reversal of the educational process cannot be achieved without employing modern technology tools and integrating them into the educational process due to change. The characteristics, skills and conditions of the current generation of people, their possession of various communication tools and technical applications, help their ability to learn quickly and skillfully [14].

In flipped learning, the class and typical homework are transferred to another curriculum, where students watch short video lectures in their homes before attending school or during the time allocated for exercises, projects, or discussions [7].

English language and its four skills are in general considered as the means that a person uses to transmit his ideas and information, and it is an effective method, starting with speaking in the early stages of a person's life, so the individual must have self-confidence to speak in front of others and the desire to do so, He also must prepare for what he wants to talk about. Training and interconnectedness of sentences and ideas can help him to be understood, because language and its skills are distinguished methods that a person uses in his relationships with others, through these skills it is possible for him to practice persuasion processes and achieve vital goals in various fields. [13].

Based on the above, the two researchers conducted a study to find out the effect of using a flipped learning strategy on developing achievement and the trend towards it among eighth-grade students in English language subject in the Hashemite Kingdom of Jordan.

A. Statement of the Problem

The feeling of the problem stemmed from the researchers' acquaintance with previous studies and literature, which referred to the use of a flipped learning strategy in teaching, as well as from the experience of one of the researchers as a teacher of English language who is a PhD holder in educational technology.

Through the work of one of the researchers as a teacher of English language, it was found that there is a low achievement of students in English language subject, through their grades, which indicated the low level of achievement among eight students in English language subject in the Hashemite Kingdom Jordan.

II. Objectives of the Study

The current study aimed to:

1) Verify the effect of using a flipped learning strategy on the development of achievement among eighth grade students in English language subject in the Hashemite Kingdom of Jordan.

2) Verify the effect of using a flipped learning strategy on developing the attitude of eighth grade students in English language subject in the Hashemite Kingdom of Jordan.

A. Research Questions

The present study calls for the answers to the following research questions:

1) What is the effect of using a flipped learning strategy on developing achievement among eighth grade students in English language subject in the Hashemite Kingdom of Jordan?

2) What is the effect of using a flipped learning strategy on developing attitude among eighth grade students in English language subject in the Hashemite Kingdom of Jordan?

B. Significance of the Study

The importance of the study is represented in the following:

1) Explaining the advantages and how to employ flipped learning strategy in learning that focuses on the learner's activities.

2) Explaining the role of both the teacher and the learner in the learning environment based on the flipped learning strategy.

3) Raising the level of eighth grade students 'achievement in English language subject, and using it in many life situations.

4) Developing students 'positive attitude towards learning, which qualifies and motivates them to continue the process of learning English language and to contribute to the elevation and position of the Hashemite Kingdom of Jordan.

5) Upgrading eighth grade students in educational and information technology skills.

6) Informing officials on the matter of curricula and teaching methods to the importance of the flipped learning method as a method within modern teaching methods that can be used in developing motivation to learn the skill of conversation, as this type of learning enables students to re-watch the explanation of a certain point more than once, or to accelerate display to reach what is required, with the possibility of viewing through a computer or mobile devices, that allows engaging in the educational process at any time.

C. Limitations of the Study

The current research is confined to the followings:

Human Frontiers: A sample of (50) students of the eighth grade who study in government schools affiliated to the Directorate of Education in the ALMazar ALShamali District in the Hashemite Kingdom of Jordan.

Substantive boundaries: A unit of the English language course for the eighth grade in the Hashemite Kingdom of Jordan.

Spatial boundaries: The current study was applied in the schools affiliated to the Directorate of Education in the ALMazar ALShamali District.

Temporal boundaries: The current study was applied in the first semester of the academic year 2020/2021.

III. Theoretical Framework of Research

The tremendous development in information and communication technology has contributed to learning, so we have to pay attention to the educational process, it is imperative to change teaching strategies to keep pace with this development. It builds the student's personality, so it will better to continue from the basic lower stage until it grows with students in all stages of their lives [1].

The idea of flipped learning came after reviewing a recent book in the West called "flipped learning. The first signs of this strategy began to appear in (2006), and then it expanded little by little until it became widespread in many countries and it was associated with the concept of flipped classrooms or flipped learning, and the idea of learning. Inverted class is an old idea, but it imposed itself extensively with the development of technology tools, but researchers disagreed about the names of flipped learning, such as flipped learning or inverted class, and some students applied it in university learning, and some students applied it in the three educational stages, and some considered this learning just a heresy, but it will be applied. Mahalla [15].

Flipped learning is defined as "an educational model in which lecturing and homework are reflected in all its forms and is a form of blended learning that includes the use of technology to benefit from learning in the classroom" [9].

Flipped learning is an educational strategy that combines the use of modern technologies such as web applications, videos, and e-books, so that they are available to the student at home; Where the student practices direct individual learning and turns the classroom tasks into interactive learning activities in small groups in the classroom to implement the educational activities and tasks assigned to the student [8].

A. Advantages of Flipped Learning

Flipped learning is characterized by being able to change constantly to meet students' needs, it is mixed with fun and vitality, with little explanation within the classes, A lot of cooperative learning, discussions and educational projects, ensure good use of lecture time, and allow more time for inquiry-based activities. The teacher takes advantage of the class more for guidance, motivation and assistance. he builds stronger relationships with the students, the student turns into a searcher for his information sources, which enhances critical thinking, self-learning, building experiences, communication and cooperation. Flipped learning provides immediate feedback to the student from teachers at the time of the lecture [17].

The flipped learning strategy keeps pace with the digital age and modern technologies and entrenches the digital culture instead of fighting it, or resisting it. It allows learners to use their mobile phones, participate in the performance of activities with each other, interact, and communicate with the teacher at the same time, It helps learners who have other connections, as job or family links, to contribute to the provision of content through the educational video, and the internet, The student can watch it at the time and place appropriate for him, to help learners who are late in the course of studies. The teacher has a lot of time in the reverse learning strategy, where he follows up the learners who are late for studies and who face problems or difficulties, it also helps them to solve and overcome them, and develop plans to address them [10].

It is also providing class or lesson time for activities instead of consuming it in the explanation that may be forgotten. The flipped classroom employs sensory learning that has proven effective in learning, so that learning is active outside the school and active in the classroom, It makes the learner as the centre of the educational process, activating strategies for brainstorming, simulation and working in groups [2].

B. Steps for Flipped Learning

The teaching process is done by learning flipped through clear steps that the teacher can take, most notably [5]:

The process for teaching a flipped learning went through some steps that the teacher should undertake such as: determining the objectives of the lesson, where the teacher creates a realistic picture of the lesson and the results that are required to be achieved at the end of the lesson, then he begins to search for educational material, including videos and animations that help in the delivery of the knowledge and skills required to be clarified to students, which helps students to understand the topic, or prepare it to serve a topic. The lesson and the use of clear and direct language for students to clarify the objectives and basic concepts in the lesson let the student return to these references whenever he wants with ease. An index of the contents is also made to make it easier for students to move between the important topics they need, in addition to trying to involve parents in the follow-up processes for lessons at home while students work on them, and the teacher holds discussion and brainstorming sessions about what the student learned, so that he takes feedback from his colleagues, which helps him to rebuild knowledge in a logical way with the need for the student to be convinced of what he learns, This process may be a starting point for a new project that the student himself plans to implement and implement.

C. Implement the Experiment

The proposed program was applied to the students of the experimental sample for research as follows:

1) The researcher clarifies to the students the study sample the nature, the objectives and importance of the educational program.

2) Distributing the educational program on a CD-ROM, and giving copies to each student from the study sample, after making sure that each student owns a computer at his home.

3) The students of the study sample watch the required lessons on the CD outside the classroom (at home) and take notes, questions and inquiries about the difficult concepts they encountered while watching the lesson.

4) After that the researcher met with the research sample students in the classroom, where at the beginning of the class the researcher asked some questions about the topic of the lesson that the students watched outside the classroom to confirm their understanding of some basic and important concepts.

5) Then, the researcher received notes, questions and inquiries from the research sample about what is difficult and unclear for them, then the researchers explained it and answered questions and inquiries.

6) After that and at the end of each lesson, the researcher made sure to review the lessons that were given to the students of the research sample.

7) After the students return to the research sample, they search, browse, develop their knowledge and review the lessons they have learned, and then they begin to see the following lessons. These steps continue until the end of the educational program. During that period, the control group was receiving educational lessons using the traditional method.

IV. Empirical Studies

The author in [19] conducted a study aimed at comparing active learning in traditional classes and active learning in flipped classrooms. The sample of the study consisted of (28) students in mathematics major at Ohio University, USA. The descriptive analytical approach was used in which data were collected through observations and personal interviews with students, the results showed students' satisfaction with the educational process using the flipped classroom, and they showed a deeper understanding of the concepts of content and retention in the flipped classroom compared to the traditional classes.

in [18] study aimed to investigate the effect of using flipped learning on the algebra subject at the University of Colorado on the students 'educational attainment, where the quasi-experimental design was used. The experimental group consisted of (135) male and female students distributed over five divisions studying algebra using the flipped learning model. The control group consisted of (166) male and female students distributed over six people taught algebra in the traditional way of lectures and homework. The results of the study showed that there were no statistically significant differences in the grades of the students of the two groups, but the results of students in the subjects in which the flipped learning was applied was slightly better than the students in the subjects that studied in the traditional way, and the trainers were in the classes that in which the flipped learning was applied, who had previous experience with verification-based learning, and cooperative learning had statistically significant differences on the final test results.

A. Commenting on Previous Studies

The studies dealt with topics related to flipped learning, as the strategy of the flipped classroom, have shown a developing in the level of achievement, such as the study of [13] and the study of [6], [21], [13], identified the effectiveness of an educational environment based on the inverted class in developing grammar and direction. [14] Identified the effect of using a flipped learning strategy on achievement and cognitive retention in teaching mathematics skills. The study of [3], aimed to identify the effect of using flipped learning in increasing achievement and developing the skills of the electronic operations course for learning resource centers. The study of showed the effect of using the flipped classroom strategy in teaching the subject of interpretation on academic achievement, The study of [19] aimed identify the evaluation of the effect of the flipped classroom model on achieving academic achievement [20]. Study aimed to compare active learning in traditional class's active learning in flipped classrooms [18]. Study aimed to find out the effect of using flipped learning in algebra [16]. Study indicated building an educational program using multimedia and investigated its impact on developing speaking and writing skills, the study of [12] showed the degree to which second-grade students possess some basic speaking skills in the light of the educational content. The current study is similar to previous studies in terms of a quasi-experimental approach such as [13] study [3] [6], [14], [5] but it is different in terms of the sample with the study of [3], the [20] study and the study [19]. The current study is the only study that includes the effect of using a reverse learning strategy on developing achievement and the trend towards it among eighth grade students in English language subject in the Hashemite Kingdom of Jordan.

V. Methodology

A. Research Methodology

The researchers used the following two approaches:

1) Descriptive Analytical Approach by reviewing studies and literature related to research variables and preparing research tools.

2) Experimental Approach in order to measure the effect of the independent variable represented by (the inverted learning strategy) on the dependent variable (achievement and the trend towards an excise learning strategy) among eighth grade students in the English language subject in the Hashemite Kingdom of Jordan.

B. Research Variables

1) The independent variable: the teaching strategy and it has two levels:

2) The experimental group that was taught using a flipped learning strategy.

3) The control group that was taught in the traditional way.

4) The dependent variable:

a) Achievement in English language.

b) The trend towards a flipped learning strategy.

C. Research Tools

1) An achievement test to measure the achievement of the research sample for English language subject.

2) A trend scale to know the students' attitudes of the research sample in the direction towards a flipped learning strategy.

D. The Research Sample

The research sample consisted of 50 students randomly, divided into two experimental groups (25) students and a control group of (25) students.

E. Research Procedures

The following is a summary of the research procedures:

1) To answer the first question:

2) Preparing an achievement test in English language subject from the eighth grade curriculum and calculating its validity and reliability.

3) Selecting the research sample from the eighth grade students in the Hashemite Kingdom of Jordan, and it was divided randomly into two groups: one group studying by using the reverse learning strategy, and the other group studying by using the traditional method.

4) The pre-application of the achievement test.

5) Conducting the basic research experiment where the experimental group is studying the learning content through the reverse learning strategy and the second in the traditional way.

6) The post application of the achievement test.

7) Interpret the results and make recommendations and suggestions.

F. To Answer the Second Question

1) Preparing the search tool represented by the trend scale.

2) Selecting the research sample from the eighth grade students in the Hashemite Kingdom of Jordan, and it was divided randomly into two groups: one group studying by using the reverse learning strategy, and the other group studying by using the traditional method.

3) Pre- application of search tools.

4) Conducting the basic research experiment where the experimental group is studying the learning content through media, and the second in the traditional way.

5) The remote application of the search tool.

6) Interpret the results, and make recommendations and suggestions.

G. Measuring Tools

After completing the implementation of the research experiment, the researchers re-applied the achievement test and the trend scale on the two research groups, the experimental group and the control group, to measure the degree of gain in their achievement of English language subject, and to know their attitudes towards reverse learning, after studying the educational content of the English language course using the reverse separation strategy. Then, after completing the application, the researchers corrected the test items according to the correction key prepared for that and monitored the students 'grades, and also monitored and collected the marks on the five axes of the trend scale, In order to statistically treat them to verify the correctness of the hypotheses, and analyze and draw conclusions.

VI. Result

The validity of the first hypothesis test and its text:

There is a statistically significant difference at the level of (0.05) between the mean scores of the experimental group and the control group students in the post application of the cognitive achievement test in favor of the experimental group.

To answer and test the validity of this hypothesis, the arithmetic averages, standard deviations and results of (T) test were extracted for independent samples to verify the statistical significance of the differences between the two research groups. The two groups were compared on two levels, namely (grammar and vocabulary) and cognitive levels (understanding, remembering, and applying) according to the course criteria.

It is evident from the Table I that there are statistically significant differences between the experimental and control groups in the items dimension in favour of the experimental group, as the calculated value of t is greater than the tabular t, and this value is a function at the level (0.01). It can be inferred from these values that teaching using the reverse learning strategy is effective in improving the achievement of eighth grade students in the English language subject in Jordan in the vocabulary of English language.

Table II shows the clear difference between the averages of the experimental group and the control group in the dimension of the Grammar, where the average of the experimental group was (10.2400), while the average of the control group was (6.9200). This difference is significant at the level of (0.01) and this is evident from the value of t. The tabular d is greater than the calculated t. The following tables shows the differences between the experimental and control group in the post application at the level of English grammar.

TABLE I. T-TEST RESULTS IN THE POST APPLICATION OF THE EXPERIMENTAL AND CONTROL GROUP IN THE VOCABULARY DIMENSION

T-test			**DS**	**M**	**N**	**The group**	**Parts the test**
Indication	**df**	**T**					
0.01	48	4.235	2.5703	9.2400	25	Experimental	**Vocabulary**
			2.0025	6.4800	25	control groups	

TABLE II. THE RESULTS OF THE T-TEST IN THE POST APPLICATION OF THE EXPERIMENTAL AND CONTROL GROUP IN THE DIMENSION OF THE GRAMMAR

T-test			DS	M	N	The group	Parts the test
Indication	**df**	T value					
0.01	48	4.661	10.2400	2.7880	25	Experimental	Grammar
			6.9200	2.2158	25	control groups	

Table III shows the high average of the experimental group compared to the control group. This difference between the two averages indicates that there are differences between both groups in favour of the experimental group. The value of T was 5.162, and this calculated value is greater than the tabular value. It is a function at the level of 0.01. Below is an illustration showing the difference between the experimental and control groups.

It is evident from the Table IV that there are differences between the averages of the experimental and control group in remember of the experimental group. It is also evident from the table that the calculated value of t is greater than the tabular value of t, and this value is a function at a significance level of 0.01. The following table compares the averages of the experimental and control group at the level of understanding.

The value of t in the Table V shows the significance of the difference between the averages of the experimental group and the control group, and this significance is at the level of 0.01 in the level of understanding. The following is a comparison between the two groups at the level of application.

It is evident from the Table VI, that there are significant differences at a level of significance (0.05). This is evident from the value of t, as the calculated value of t (2.194) is greater than the tabular t. This indicates that the difference between the experimental and control group is a fundamental difference.

It is evident from the foregoing that the experimental group outperformed the control group in the post application, and thus the assumption of the first research is accepted.

The results of the current study are consistent with the results of the study of [13], [3], [6], and [14], and differed in terms of the sample with the study of [3] and the [20] and . [19].

The previous results related to the first hypothesis can be interpreted as follows:

The results indicated that there is a statistically significant difference between the mean scores of the experimental group and the control group students in the post application of the cognitive achievement test in favour of the experimental group, who learned using the strategy of inverse separation, compared to the control group that learned by the usual method, and this indicates that the use of the reverse separation strategy had the effect of increasing academic achievement in English language subject for eighth grade students.

This result may be attributed to the lessons prepared for students (outside the classroom) and to the use of the reverse classroom strategy, which helped to invest the time of direct meeting in the classroom and exploited it to accomplish all the educational activities and tasks to be achieved, and this in turn enriched the students 'learning of the research sample, which resulted in to develop knowledge and thus raise the level of achievement.

It is also possible to explain this result to the fact that the use of the reverse separation strategy has found approval and acceptance from the research sample because they learned in a new interesting and enjoyable method which raised their enthusiasm and their desire to learn better and thus increased their achievement.

The second hypothesis test and its text: There is a statistically significant difference at the level of significance (0.05) between the mean scores of the experimental group and the control group students in the post application of the trend scale in favour of the experimental group.

To answer and test the validity of this hypothesis, (T) test was used for independent samples to find the difference between the averages of the experimental and control group in the measure of the trend towards using the strategy of inverse separation and to find out whether these differences are significant or not. The following are the averages and standard deviations of the experimental and control group and the value of T.

The Table VII shows the big difference between the averages of the experimental group and the control group in favour of the experimental group, where the difference between them was 36.52, and the value of t in the total of the scale was 13.656 and this value is a function at the level of (0.01). The trends of the experimental group are the direction of the reverse separation strategy compared to the control group that was taught using traditional teaching methods, and this means accepting the assumption of the second research. [5] and it differed in terms of the sample with the study of [3] and the study. [19].

The previous results related to the second hypothesis can be interpreted as follows: The results indicated that there was a statistically significant difference between the mean scores of the experimental group and the control group students in the post application of the trend scale in favour of the experimental group, and this indicates that the use of the inverse separation strategy had an effect on the development of students 'attitude towards it. This result may be attributed to the fact that the use of multimedia from audio-visual means through video clips, educational flashes and images, which has the effect of engaging more than one sense in perceiving concepts, stimulating their thinking and retaining them for a longer period than the period of students in the traditional group learning, which contributed to improving and developing students' orientation towards using the reverse separation strategy. Perhaps the teamwork that is characterized by the reverse separation strategy is one of the advantages that have contributed to reaching this result, as it embodies the feeling of belonging to cooperative work and self-confidence, which in turn contributes to increasing the motivation that is among all students when starting to achieve success by completing the required tasks and activities. Positive success for some students is transmitted to the rest of the students, even the weak ones, to strive for all of them, exerting their utmost effort in completing the tasks and activities required of them, which greatly contributed to improving and developing students' tendency towards using the reverse classroom strategy.

TABLE III. RESULTS OF THE T-TEST IN THE POST APPLICATION OF THE EXPERIMENTAL AND CONTROL GROUP IN TOTAL ACHIEVEMENT IN ENGLISH LANGUAGE

T-test			**DS**	**M**	**N**	**The group**	**Parts the test**
Indication	**DF**	**T value**					
0.01	48	5.162	4.7003	19.4800	25	Experimental	**Total Summation**
			3.5473	13.4000	25	control groups	

TABLE IV. RESULTS OF THE T-TEST IN THE POST APPLICATION OF THE EXPERIMENTAL AND CONTROL GROUP ON THE LEVEL OF REMEMBER

T-test			DS	M	N	The group	Level the test
Indication	DF	T value					
0.01	48	5.162	3.4278	9.000	25	Experimental	Remember
			1.8947	5.5600	25	control groups	

TABLE V. THE RESULTS OF THE T-TEST IN THE POST APPLICATION OF THE EXPERIMENTAL AND CONTROL GROUP IN THE LEVEL OF UNDERSTANDING

T-test			**DS**	**M**	**N**	**The group**	**Level the test**
Indication	**DF**	**T value**					
0.01	48	2.664	2.0066	6.1200	25	**Experimental**	**Understanding**
			1.6906	4.7200	25	**control groups**	

TABLE VI. RESULTS OF THE T-TEST IN THE POST APPLICATION OF THE EXPERIMENTAL AND CONTROL GROUP AT THE LEVEL OF APPLICATION

T-test			**DS**	**M**	**N**	**The group**	**Level the Test**
Indication	**DF**	**T value**					
0.05	48	2.194	0.9345	4.0400	25	**Experimental**	**Application**
			1.4583	3.2800	25	**control groups**	

TABLE VII. T-TEST RESULTS IN THE POST APPLICATION OF THE TREND SCALE TOWARDS USING THE REVERSE SEPARATION STRATEGY FOR THE EXPERIMENTAL AND CONTROL GROUPS

indication	**DF**	**T value**	**DS**	**M**	**N**	**The group**	**The phrase number**
0.01	48	13.656	9.70172	122.0400	25	**Experimental**	**Total**
			9.20199	85.5200	25	control groups	

VII. RECOMMENDATION

In light of the findings of the current research, the following recommendations can be made:

- Making use of the standards and the proposed educational model in the current research in the field of learning the English language.
- The application of multimedia programs in using the flipped learning strategy to raise the level of students in the basic stage in academic achievement.
- Expanding the application of e-learning and blended learning to improve students 'attitudes towards using the flipped learning strategy to learn the English language subject.
- Holding training courses for teachers on using the reverse learning strategy.

A. Implications

1) Studying the effect of using interactive multimedia programs in the flipped classroom on the development of achievement and the trend towards e-learning among students in various disciplines and at various academic levels.

2) Study the extent of the needs of educational institutions in the Hashemite Kingdom of Jordan for the material and scientific requirements to create a mirrored e-learning system.

3) A comparative study between the role of students at the secondary level in the traditional class and the flipped class in the English language subject.

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Analysis and Optimization of Delegation-based Sequenced Packet Exchange (SPX) Protocol: A Kailar Logic Approach

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***Abstract*—Accountability within electronic commerce protocols has tremendous significance, especially those that require answerability for the actions taken by participants. In this study, the authors evaluate the delegation of accountability based on the Sequenced Packet Exchange (SPX) protocol. The study emphasizes the concept of provability as a benchmark to formalize accountability. Moreover, this paper proposed a new framework that enables principals to delegate individual rights to other principals and how the delegator's accountability is handed over or retained, which provides the crucial functionality of tracing how accountability is distributed among principals within a system. The study provides a novel solution to accountability challenges and analysis of protocols, such as introducing novel conditions for distributing essential credentials among the grantor and the grantee and analyzing delegation-based protocols. The approach adopted will help prevent potential compromises of the integrity of online transactions. By extension, it will also serve as a best practice solution for settling legal disputes among principals.**

***Keywords*—Delegator; accountability; grantor; Kailar logic; principal; client; delegate; grantee**

I. Introduction

The advent of cutting-edge technologies such as Big Data, Cloud Computing, the Internet of Things (IoT), and Web-Based Distributed applications has increased the need for electronic commerce transactions and other web-based services. Apart from revolutionizing the way business is conducted. Research has shown that companies that leverage these technologies gain massive profit margins compared to legacy systems [1].

Also, electronic commerce has progressively developed because of the rapid increase in businesses migrating to the web, which has opened up a new paradigm for computer scientists willing to dedicate their time and resources to the research, design, development, and optimization of protocols that provide security, authentication, authorization, verification, and confidentiality including accountability of internet-based commercial transactions [2], [3].

Lack of accountability among principals in any electronic transaction can introduce deception because of the prevalence of fraud and malicious activities on the internet. Consequently, this can make the electronic transaction process very unreliable. Therefore, proving accountability among principal actors deserves an equal degree of importance as offline transactions. For instance, in a data breach or privacy violation, a network administrator may delegate backup service of sensitive data to junior staff. Therefore, it will be essential for the parties to prove to a third party about their conduct for accountability purposes.

The design of efficient and error-free electronic transaction protocol has been a challenging task in computer science. Computer scientists often rely on formal analysis to detect, optimize flaws and redundancies in the design and production stages. However, most analysis methods before Kailar logic deal with various entities' beliefs and protocols. Therefore, this paper presents a formal analysis method using Kailar Logic [4]. The ability of principals to prove accountability in any electronic transactions is analyzed and evaluated, including how accountability is assured using existing protocols [5], [6].

There has been significant work on other protocols, but research on the analysis of delegation-based protocols is yet to be adequately explored. In this work, the author uses the Kailar Logic analysis method and techniques based on the Delegation-Based SPX protocol to prove accountability among participating principals. In this context, the primary objective of proving accountability and provability among participants within the protocol form the basis of the study [7].

A. Accountability

Accountability in scientific journals is "the state whereby a principal is associated with an action that can be proven to a third party," wherein the third party is different from the prover and the initiator [4]. Similarly, Accountability also means a particular subject can prove to a third party that it is responsible for initiating a specific action or object. However, in this paper, the focus of Accountability is on internet transactions. How relevant principals involved in the transaction keep track of the evidence of each party. For instance, the whole transaction process should be evident or transparent to all participants [7].

Since the goal of the Kailar framework (Kailar Logic) is to provide Accountability among participants of a given Internet transaction, thus ensuring non-repudiation of the parties, which is made possible with the help of transaction records or digital

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fingerprints. The whole concept hinges on tracking every transaction end-to-end during the process and, most importantly, the source or origin. The result can be used as evidence to resolve legal disputes among participants of any online Internet transaction. This paper uses Accountability based on the above definition [8].

B. Summary of Provability and Belief

A statement y is believed by an individual if he or she is convinced of it. However, suppose a participant can convince another participant about statement y. In that case, it means the participant can prove statement y, which is achieved through the collective conveyance of the validity of statement y to an audience through a set of statements referred to as proof of statement y. Similarly, the capability to produce the required set of statements that can convince an audience about statement y is the capability to prove statement y [9].

C. Asymmetric and Symmetric Encryption

The past decades have witnessed the use of Symmetric Encryption algorithms in many systems and protocols. The encryption scheme is where a single secret key is used to encrypt and decrypt a message possessed by all the participants involved in the communication. Co-relating this definition to the new concept of Believe and Provability, assuming we have two participants in an Internet transaction, namely A and B. If B receives a message encrypted with a key he possesses, which he did not send, he has believed that A sent it. However, he cannot prove this to a third party, making this approach unsuitable for this paper.

Nonetheless, with the growing vulnerabilities on the Internet, the need for a new approach in the form of Asymmetric Encryption is required. This encryption scheme involves two related keys, one public, and the other secret or private keys. The former (public) is used to encrypt the message while the latter decrypts the same message. Moreover, while the private key is kept secure by the participating entities, the public key is made available to everyone to encrypt the message they wish to send. This approach addresses the gap in the symmetric scheme because it does not rely on trust but instead keys belonging to participants themselves, therefore providing accountability. However, they are also susceptible to tampering. Consequently, this work considers using asymmetric encryption techniques for the entire analysis process of the proposed approach.

Based on existing literature, security researchers have made significant progress in protocol analysis. However, the degree of exploration into protocol analysis detailing characteristics of accountability is sparse. In this study, accountability analysis of delegation-based protocols is explored. This inspired the notion that delegation is about the standard technique of conveying accountabilities among principals. The main contributions of the paper are the following:

- Developed a new framework that enables principals to delegate individual rights to other principals and went further to show how the delegator's accountability is either handed over or retained.
- Provides a novel solution to accountability challenges and analysis of protocols.
- The result of the approach will help prevent potential compromise of the integrity of online transactions. It will also serve as solution for legal disputes settlement among principals.

The rest of the paper is organized as follows: Section 2 discusses the related work. Section 3 deals with Kailar Logic and its properties, and Section 4 summarizes the symbols and theories utilized in this work. Similarly, Section 5 discusses the proposed Delegation-Based SPX protocol, and finally, Section 6 concludes with a summary.

II. Related Work

Determining which protocol fulfills or lacks the necessary accountability for electronic commerce and other domains, the past decades have seen several researchers proposed quite a few accountability logics for electronic transactions. Therefore, this section discussed a few of the works accomplished by researchers in analyzing accountability.

In [8], the authors stressed the importance of accountability and how it can resolve disputes among participants in any internet transaction. They stated that accountability enables each party to be aware of what has been done and who is responsible for every action performed during the transaction, consequently holding participants involved in a transaction accountable for their actions with undeniable justification. Furthermore, the authors stress that the primary goal of accountability is to use sufficient recorded evidence to resolve disputes among participants, which could be used in a court of law if disputes arise at the end of a transaction, however, despite many researchers' claim that they proposed a protocol that meets the accountability need of internet transactions. The authors of this paper have argued that such claimants are yet to meet the standards needed to eliminate disputes effectively.

The need to address this gap inspired them to propose a new accountability security property for Internet transactions. In their approach to enhancing security, the following two accountability properties were proposed. The first property is centered on responsibility by harvesting evidence for all activities made during Internet transactions, which participants will use to resolve disputes if it arises. Finally, the second property involves responsiveness, availability of evidence, and the speed at which trusted third participants send evidence to external participants to resolve disputes.

A detailed and reliable accountability analysis approach using a mobile payment protocol is proposed in [10]. The proposed protocol comprises five engaging parties: client or payer, who purchases services and goods from merchants, a merchant or payee denoted as a store, or a person who has services and goods to sell to the client. Similarly, a financial company denoted Mobile Network Operator (MNO) serves as a financial company for both the payer and the payee.

Finally, the Time stamp center (TSC) for authorization among the parties. The protocol underscores seven phases with specific functions. They are as follows: payment initialization, payment subtraction request, payment authorization request, payment confirmation request, payment confirmation response, payment authorization response, and payment subtraction response. The major drawback of the protocol is the use of symmetric encryption, which is the main focus of this paper. Also, the protocol provides weak authentication, such as providing only on payer side. This paper therefore deduces that the approach in this protocol can lead to potential fraud by the attacker. As a result, it lacks all the attributes of accountability.

Similarly, the vulnerability of KN's logic, such as lack of reasoning for accountability in symmetric key and revealing secret information to a verifier, was identified by the authors of [11]. Therefore, to mitigate these challenges, a novel logic (KP's logic) is proposed that will only send the required information to the verifier, and the authors claimed that their approach could eliminate disputes among participants. Nonetheless, research has shown that KP's logic lacks the critical reasoning for accountability in symmetric encryption, inspiring the authors in [12] to extend the KP's logic and proposed the KSL's logic, which has the robustness of analyzing protocols for both asymmetric and symmetric encryption processes. However, their proposed protocol details were never described in detail, but information for more reading was provided in their reference section [13].

Kailar is probably the first to propose a modal logic with the primary objective of reasoning about accountability. It continues to highlight Kaila's definition for accountability as concerned with the ability to prove the association of an originator with some action to a third party without revealing any private information to the third party." The prover is the party who can prove such statements, while the verifier is the party being convinced of the proof. Kailar has adopted the "CanProve" modal operator to validate the notion of accountability, for instance, "A CanProve x to B," where A and B signify the prover and verifier, respectively, and x stands for a general statement about some action [14].

Nevertheless, research has shown that Kailar's approach can only provide reasoning for the accountability of signed messages but is insufficient for analyzing complex cryptographic messages such as hashed messages and signed encrypted messages. Also, quite a few researchers have stated that Kailar's prover CanProve x to verifier cannot justify the predicates and rules because of its lack of semantics and finally does not reason about verifiers [4], [15]. Therefore, they are casting doubts about the correctness of Kailar's calculus, which inspired Kessler and Neumann to adopt a new modal logic to mitigate this challenge. They claimed to have handled this concern found in Kailar's novel framework.

To mitigate the identified concerns in Kessler and Neumann's (K&N) and Kailar's framework, the authors in [16] presented a novel modal logic that extends the idea of Kessler and Neumann, which applies the idea of provable authorization on private information. The prover efficiently sends only the required information to the judge during dispute resolution, enabling proving some statements without revealing secret information. This approach has claimed to be very efficient and safe because the prover can prove statements without revealing any private information to the verifier. The authors extend K&N's logic in two phases used to analyze both iKP and SET protocol, respectively. However, they claimed the message format of SET has led to the lack of accountability after all the two analyses were conducted. Nevertheless, a successful proof of money accountability was achieved for the iKP due to its message format.

Finally, the first automated model of accountability in electronic payment protocol centered on Blanchet probabilistic polynomial calculus was proposed by the authors in [17]. Injective or Non-injective correspondence is used to express the accountability of money and goods, respectively, using CryptoVerif automated tool. The authors were able to automatically analyze the accountability of the money and goods of electronic payment protocols. This approach is found to be very efficient and valuable as it is regarded to be the first of its kind in the analysis of accountability with the electronic transaction [18].

III. Kailar Logic

In 1996, Rajashekar Kailar introduced a new Kailar Logic framework to analyze accountability among participants within electronic-commerce transactions or other related protocols requiring accountability analysis. The rationale behind Kailar Logic is to ascertain the accurate establishment of the origin of a message among the participants involved in a protocol exchange. For instance, participants involved in a protocol exchange or electronic transaction treat signed messages as undeniable statements. Therefore, to convince another party through the use of proof of statements in a sequence of operations will consequently make that statement true.

Before the advent of the Kailar Logic, most of the logic was based on a belief approach that has yet to address the needs of modern protocols adequately. The introduction of Kailar Logic provides accountability analysis of protocols and enables the detection and deletion of redundant information within analyzed protocols [4].

Kailar Logic uses the following six (6) logic components as signs and four (4) postulates as explained in the next section.

A: Sender of message

B: Receiver of message

SK_p: Secret Key of party **P**, used for signing digital signatures

PK_p: Public Key of party **P**, used for encryption and for verifying signature signed under **SK_p**

h(x): Output of one-way hash function **h()** with message ***x*** as its input

$\{x\}PK_p$: Encryption of message **x** under **P**'s public key, **PK_p**

$\{x\}SK_p$: Message **x** signed with **P**'s Secret key **SK_p**

$\{x\}k$: Symmetric-key encryption of message ***x*** under a session key **k**.

A. Components of Kailar Logic

This paper considers only a few of Kailar Logic statements and postulates that would be needed to analyze the protocol's accountability. Also, due to restriction of content, these statements and postulates are briefly explained.

1) Strong Proof: "A CanProve x" and Weak Proof: "A CanProve x to B": Firstly, the Strong Proof: "A CanProve x" is the proofing of x to a third party B by principal A, which denotes that A can persuade the principal B of statement x by executing a series of sequence of operations and not disclosing any secret of y(y≠x) to B. Finally, Weak Proof: "A CanProve x to B", is the process of weakly proving statement x to principal B, which means principal A can persuade the principal B of statement x after performing a sequence of operations that do not disclose any secret about y(y≠x) to B. However, to attain accountability in this work, this paper only use the Strong Proof: "A CanProve x" [4].

2) Signature Verification Component: "K_a Authenticates A": This statement denotes that the signature of principal **A** can be authenticated using the key $\mathbf{K_a}$. Therefore, to fulfill the needs of accountability analysis in this paper, any encrypted statement with $\mathbf{K_a}$ can be associated with principal **A**. Also, since it was mentioned earlier that this paper would be using asymmetric encryption in this work, $\mathbf{K_a}$ can safely be denoted as the public key and $\mathbf{K_a^{-1}}$ to be the private key to enhance the easy understanding of this statement.

*3) Message Interpretation: **"x in m":*** The statement ***"x in m"*** implies that ***x*** is one or several plaintexts or ciphertext fields or groups found in the message m, which is commonly just referred to as the interpretable fields or groups in many works of literature. However, this interpretation needs to be clearly defined by the protocol designers because it is protocol specific.

*4) Declaration Component: **"A Says x":*** The declaration ***A Says x*** implies that the principal ***A*** is answerable for the statement ***x*** and any other statement implied by the ***x***, making ***A*** to be accountable for ***x***. Furthermore, if ***A*** says any statement composed of more than one part, ***A*** is accountable for all of those statements. For instance, if A declares the cascade of two formulas ***x*** and ***y***, then ***A*** declares each of them, ***A Says (x, y) ⇒ A Says x*** and ***A Says y***.

5) Message Receiving Component: "A Receives m SignedWith K^{-1}": The message receipt denotes that the Principal ***A*** receives a message ***m*** signed with a private key $\boldsymbol{K^{-1}}$. Also, in this definition, the signatures and contents associated with the messages are denoted by ***m***. The following postulate is used for analysis in most of the existing literature. It indicates that ***x*** is a combination of fields or an interpretation of a field within the message.

$$\frac{\text{A Receives m SignedWith K} - 1;\ \text{x in m}}{\text{A Receives x SignedWith K} - 1}$$

6) Trust Component: "A IsTrustedOn x" and "A IsTrustedOn x by B" : Finally, the global and no-global trust denotes that if principal ***A*** is trusted on statement ***x***, then ***A*** has the power to endorse ***x*** and equally liable for making statement ***x***. However, to be specific, when ***A*** is globally trusted on ***x*** (***"A IsTrustedOn x"***), then it means ***A IsTrustedOn x*** by all principal, in contrary, when ***A*** is Non-globally trust on ***x*** (***"A IsTrustedOn x by B"***), then it means that the principal ***A*** is accountable to prove to principal ***B*** that ***A*** is responsible for statement ***x***, which means that ***A*** is trusted on statement ***x*** [4].

B. Postulates of Kailar Logic

This segment introduces the properties of accountability by using some of the notations explained below. Although Kailar Logic has lots of postulates, some of which are general properties and others are specific to electronic messages that are digitally signed. However, this paper will only introduce the necessary postulates to analyze accountability among participants with an electronic transaction. Therefore, below are some of the utilized postulates, and the following form will be used to express the postulates presented in this paper.

$$\frac{P;\ Q}{R}$$

The above postulate signifies that if the statement P and Q hold concurrently, then it means the resulting statement R equally holds, and P and Q signify the basis of the rule.

1) Conjunction: This postulate denotes that if the principal ***A*** can prove that both statement ***x*** and ***y*** hold, consequently ***A*** can prove that the conjunction ***x∧y*** is true. It is instrumental in analyzing the accountability among principals because to examine the proving scope of each principal, this postulate can compose their statements to conclude. Similarly, the individual statements signed and sent across the network can be used to hold principals accountable for the composite statements they have made.

$$\frac{A\ CanProve\ x;\ A\ CanProve\ y}{A\ CanProve\ (x \wedge\ y)}$$

2) Inference: In [4], principal ***A*** can prove ***y*** holds if ***A*** can prove ***x*** and at the same time ***x*** denotes ***y***, which also means since ***x*** implies ***y*** and ***A*** can prove ***x***, then ***A*** can prove that ***y*** is real. Statements such as (***x⇒y***), which is used to express the interpretation of signed messages, should always be explicitly defined by the protocol designers, and usually used in the analysis to derive inferred results from statements that are ascertained.

$$\frac{A\ CanProve\ x;\ x \Rightarrow y}{A\ CanProve\ x}$$

3) Signature Rules: When ***A*** receives a message ***m*** signed with key $\boldsymbol{K^{-1}}$, and at the same time the message ***m*** contains statement ***x***, and principal ***A*** can prove that during the message signature, the key ***K*** authenticates the principal ***B***. Therefore, ***B Says x*** can indeed be proved by the principal ***A***. This postulate plays a significant role in helping to prove that principals are accountable for the messages signed by them.

A Receives (m SignedWith K^{-1}); x in m;

$$\frac{A\ CanProve\ (K\ Authenticates\ B)}{A\ CanProve\ (B\ Says\ x)}$$

4) Trust Rules: As mentioned earlier, the paper will focus on the postulates that have importance toward the accountability analysis. Therefore, other trust postulates will not be primarily included in this paper but will be used as a prerequisite to get to the results of the trust postulate used in this paper. Consequently, newbies to this framework will need to go and read the missing trust postulates. This trust postulate denotes that if the principal ***B***, who is an authority on ***x***, and at the same time ***Says x***, can be proved by principal ***A***, then ***A*** can prove that the statement ***x*** holds. The outcome below can be attained by applying ***Conjunction***, ***Inference*** on $\mathbf{T_1}$, which is not presented in this work, and finally applying $\mathbf{T_2}$ on the resulting statement. Note that the author decided to exclude both $\mathbf{T_1}$ and $\mathbf{T_2}$ in this work.

A CanProve (B Says x);

$$\frac{A\ CanProve\ (B\ IsTrustedOn\ x)}{A\ CanProve\ x}$$

IV. Summary of the Symbols and Theories

This paper, as mentioned earlier, will follow the general communication protocol, which has a group of principals exchanging messages among each other, commonly denoted by uppercase letters, for instance (X, Y…). Similarly, the message interpretations are the statements by each message and are commonly denoted by lowercase letters (x, y …), and these terms will enhance the primary objectives of proving the origin of the message based on the capacity of the involved principals. For instance, a proof of *statement x* can be regarded as a set of operations that convinces another principal of *statement x*. However, the steps of the proof are mainly dependent on the specifications of the designed protocol. Therefore, this paper will not stress on the steps of proof but instead the analysis of accountability within the Delegation-Based Sequenced Packet Exchange (SPX) [19]. Furthermore, this paper uses the Greek Capital Letter Psi (Ψ) to represents the set of rights that a principal can execute. Equally, the paper introduces a new term called CanExecute, which symbolizes the ability a principal has to execute certain delegated or given rights. For instance,

"X CanExecute Ψ.": It means principal X has all the rights to execute the assigned rights to Ψ. Similarly,

"X CanExecute Ψ with K.": This means that principal X can only execute the rights assigned to Ψ with the key K, and in both examples, principal X will be held responsible for those executed rights. As mentioned earlier, rights could mean objects or actions to be executed.

A. Synopsis of the Newly Introduced "X CanExecute Ψ" Postulates

As discussed above regarding the "*X CanExecute Ψ*" postulate, this section will not only help the readers to understand the full capabilities of this postulate, but it will also highlight its significances in the analysis stage. A principal providing can execute a right or set of rights he or she has permission to execute from another principal, who could be a Trusted Authority in this analysis, such as administrator of computer systems and networks, as mentioned in the introduction. Expressly, a principal can only delegate the rights he or she can execute to another principal. For instance, *principal X* can only delegate a set of rights *Ψ* to *principal Y* only if it has the right to execute the rights listed in *Ψ*. To conclude, the above-delegated rights Ψ executed by to Y should hold *principal X* answerable for delegating these rights to *principal Y*, and there must be authentication in place when *principal Y* executes the delegated rights Ψ. Therefore, this paper introduces two new postulates to support our analysis, and they are denoted as [Ẍ], and [Ỹ], respectively.

1) [Ẍ]: The postulate above, "[**Ẍ**]", denotes that the listed set of rights in **Ψ** can be executed by *principal X*, while in the second statement, he or she also delegates to *principal Y* to execute the same rights. Finally, the postulate's last statement denotes that in executing the delegated rights listed in **Ψ**, *principal Y* will be authenticated with the key $\mathbf{K_{Del}}$. However, to illustrate the magnitude of power a principal has when delegated to execute given sets of rights, we can omit the authentication key **K**, which means once a principal "*X CanExecute Ψ with K*", then principal "*X CanExecute Ψ* " without the key **K**, which the author defined in [**Ỹ**].

X CanExecute Ψ;

X Says (delegation of Ψ to Y);

$$\frac{(KDel\ Authenticates\ Y);}{Y\ CanExecute\ \Psi\ with\ KDel}$$

2) [Ỹ]: Likewise, the above postulate "[**Ỹ**]" will be employed during the accountability analysis. This postulate will enable the efficient proof of principals' answerability for the given or delegated sets of rights to execute. For instance, if "*Y CanExecute Ψ with* K_{Del}" where **Y** is the delegate, then our analysis should be able to justify "delegate CanProve (*delegate CanExecute Ψ with* K_{Del}), in which $\mathbf{K_{Del}}$ represents the delegation key of the protocol. Likewise, the delegator's proof of not being responsible for the delegate's actions is equally significant. For example, if "**X** Says (*delegations of Ψ to Y*)" where **X** is the delegator, and **Y** is the delegate, then principal **X** should be able to prove that **Y** is answerable for the actions executed on the delegated set of rights listed in **Ψ**, which can be denoted as delegator (**X**) CanProve (K_{Del} *Authenticates delegate(Y)*)

$$\frac{X\ CanExecute\ \Psi\ with\ K;}{X\ CanExecute\ \Psi}$$

B. The Deletion-based Sequenced Packet Exchange (SPX)

In this section, a Delegation-Based Sequenced Packet Exchange (SPX) is used to study how delegates can hold or prove that the delegators are answerable for their actions during an electronic transaction and vice visa. The authors of [19] highlighted that in SPX, the principals exchange authentication tokens to authenticate each other, which authorizes the secure exchange of session keys. Furthermore, this paper focuses on the analysis of accountability and the delegation capability SPX provides but not the detailed explanation of the SPX protocol. Therefore, readers can refer to [19] for more information. Regardless, this paper provides a brief synopsis of the content of the SPX authentication exchange:

Client CanProve (K_s Authenticates *Server*) [G1]

Server CanProve (K_c, Authenticates *Client*) [G2]

Delegate CanProve (K_{Del}, Authenticates *Delegator*) [G3]

The description of the protocol is as follows:

1. C → CDC: S
2. CDC → C: $\{\{S, K_s, T_{A1},\} K_{TA1}^{-1},\}K_{CDC}^{-1}$
3. CDC → C: $\{K_{Del}, T,\} K_c^{-1}\{K_{des}\}$ Ks; $\{K_{Del}^{-1}\} K_{des}$
4. S → CDC: C
5. CDC → S: $\{\{C, K_c, T_{A2},\} K_{TA2}^{1},\}K_{CDC}^{-1}$
6. S → C: Response (Accept / Reject)

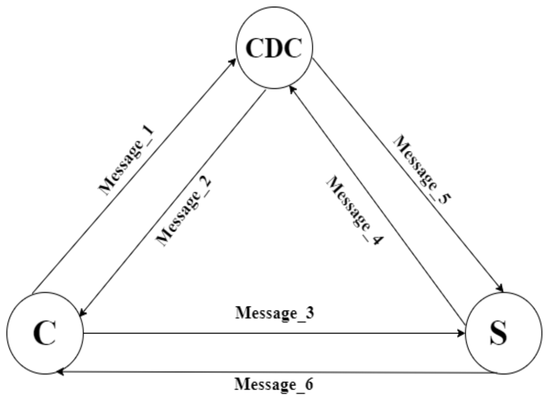

Fig. 1. The Tardo-Alagappan Delegation-Based SPX Protocol.

This section explains a classical Delegation-Based SPX protocol presented in Fig. 1, using the above notation (1-6). Firstly, **C** denotes the Claimant, **S** denotes the verifier, while **CDC** is the Certificate Distribution Center. The first message (*message_1*) signifies **C** is sending the identity of the verifier to **CDC**, then **CDC** responds with a certificate belonging to **S** issued by the Trusted Authority1 (**TA_1**) in the second message (*message_2*), which is encrypted with the private key of **CDC**. Next, **C** sends its delegation public key in the following message (*message_3*), a secret **DES** key **Kdes**, encrypted with **S**'s public key, and the private delegation key encrypted with this secret key. To verify the signature on the delegation key **C**, **S** gathers the above information, sends the certificate of **C** to **CDC**, and gets a key certificate issued by Trusted Authority2 (**TA_2**) from **CDC** (*message_4* and *message_5*). Finally, the public key of **C** in the received certificate was employed by **S** to authenticate the signature of **C** on the delegation key. **S** will respond in the last message ((*message_6*) with an "Accept" only if he or she is convinced with **C**'s delegation key; else, respond "Reject." Note that **TA_1**, **TA_2**, and **CDC** can make certain statements based on the role of Trusted Authorities.

The primary objective of the protocol is for *principal S* to securely obtain a delegation key from *principal C*, which means *principal C* is authorizing *principal S* to serve as a delegate by allocating a set of rights that belongs to **C** with **S** for a given period, defined as **T**. However, it is equally important to note that this protocol is not designed to delegate accountability among principals since the transferred rights to *principal S* still belong to *principal C*. Consequently, it is infeasible to analyze accountability within principals, thereby necessitating the proposal of a new framework in this paper.

It is important to note that from now onwards, this work will be using Cyrillic Capital Letter Omega **Ѡ** to represent the messages in the diagram like **Ѡ$_1$, Ѡ$_2$, …, Ѡ$_N$**.

C. Reformulating the Deletion-Based Sequenced Packet Exchange (SPX)

This section, reformulated the protocol description given above based on the notations adopted by Kailar's logic in [20]. It targets the statements or goals mentioned earlier, such as *(KS, Authenticates S), (K_{Del} Authenticates C during T) and (KC Authenticates C)* in the protocol description, which express the semantics of **Ѡ$_2$**, **Ѡ$_3$**, and **Ѡ$_5$**, respectively, and this has a great significance to the subsequent analysis of the protocol. The following denotes the protocol message interpretation based on Kailar's notation and the protocol's relevant messages.

1) C Receives (((K_S, Authenticates S) SignedWith K_{TA1}^{-1}) SignedWith K_{CDC}^{-1}).

2) S Receives (((K_{Del}, Authenticates C during T) SignedWith K_C^{-1})).

3) S Receives (((K_C, Authenticates C) SignedWith K_{TA2}^{-1}) SignedWith K_{CDC}^{-1}).

However, irrespective of the chronological ordering of the above messages, it should be noted that the Ѡ$_5$ "*S Receives (((Kc, Authenticates C) SignedWith K_{TA2}^{-1}) SignedWith K_{CDC}^{-1})*" which derives the key K_C for authenticating the signature of Ѡ$_3$ has to come first during the analysis stage as a result of Ѡ$_3$ needing the key K_C for signature authentication.

V. Analysis of the SPX Protocol

The analysis will start with SPX without delegation, and the objective of this section is to justify if the SPX protocol without delegation will be able to still prove accountability among principals by using the delegation key (K_{Del}) as mentioned earlier based on Kailar's framework, denoted as "*S CanProve (K_{Del} Authenticates C)*." In this case, both the delegate and the delegator's objective is to prove what they are answerable for and the answerability of the other principal. Nevertheless, because the same key (K_{Del}) is used to authenticate both the delegator and the delegate, there will not be any accountability. For instance, the Goal "*S CanProve (K_{Del} Authenticates C)*" where *S* is the delegator and C is the delegate, will hold the principal S accountable for C's actions even though she has delegated all the rights to C because the key K_{Del} authenticates S, therefore losing accountability in this process. As a result, this paper concludes that SPX, without support for delegation, cannot guarantee accountability among the principals involved. The following section provides the analysis of the improved Delegation-Based SPX protocol.

A. Summary of the Proposed Delegation-Based Accountability Protocol

After comprehensive research on protocols proposed for delegation tokens such as in [21]–[23], this paper proposed an optimized protocol, which has the functionality of allowing principals to delegate certain individual rights to other principals, which also means the delegation of a principal's accountability to another principal who is responsible in the event something went wrong during a transaction. In this approach, the author makes some assumptions such as;

1) The ability of principals to have access to digital signature services and generate public key pairs.

2) The inclusion of authentication keys within the public keys attain by principals for the verification of digital signatures.

3) Excluding principal authentication, this is assumed to be handled at the start of the protocol. Therefore, below are some of the explanations for the terms and concepts introduced for the proposed protocol.

- Firstly, $\underline{\mathbf{R}}$ is the grantor, while $\underset{\cdot}{\bar{\mathbf{R}}}$ is the Grantee.
- The sets of delegated rights to be executed are represented by $\mathbf{\Psi}$ as mentioned earlier.
- The period of the delegation token **T** is represented by **TS.**
- The key pairs authentication for Grantor and Grantee are represented by ($\mathbf{K_{\underline{R}}}$, $\mathbf{K_{\underline{R}}^{-1}}$) and ($\mathbf{K_{\underset{\cdot}{\bar{R}}}}$, $\mathbf{K_{\underset{\cdot}{\bar{R}}}'^{-1}}$) respectively.
- The delegation key pairs ($\mathbf{K_{Del}}$, $\mathbf{K_{Del}^{-1}}$), is the use by the Grantee to execute the list of rights in $\mathbf{\Psi}$**.**
- Finally, $\acute{\mathbf{M}}$**,** $\acute{\mathbf{M}}'$**,** and $\acute{\mathbf{M}}''$ will be described within the proposed protocol listed below.

The proposed delegation-based accountability protocol is listed as follows, and its represented by ƛ_1, ƛ_2, …, ƛ_N.

[ƛ_1]: $\underline{R} \rightarrow \underset{\cdot}{\bar{R}}$: $\underline{R}$, $\underset{\cdot}{\bar{R}}$, $\acute{M}$, $K_{\underline{R}}^{-1}$ ($\acute{M}$)

[ƛ_2]: $\underset{\cdot}{\bar{R}} \rightarrow \underline{R}$: $\underset{\cdot}{\bar{R}}$, $\underline{R}$, $\acute{M}'$, $K_{\underset{\cdot}{\bar{R}}}^{-1}$ ($\acute{M}'$)

[ƛ3]: $\underline{R} \rightarrow \underset{\cdot}{\bar{R}}$: T = [$\underline{R}$, $\underset{\cdot}{\bar{R}}$, $\acute{M}''$, $K_{\underline{R}}^{-1}$ ($\acute{M}''$)

In the first message (**[ƛ_1]**), the $\acute{\mathbf{M}}$ signifies that "$\underline{\mathbf{R}}$ wishes to delegate to $\underset{\cdot}{\bar{\mathbf{R}}}$ accountability for $\mathbf{\Psi}$**.**" Similarly, $\acute{\mathbf{M}}'$ equally signifies that "$\underset{\cdot}{\bar{\mathbf{R}}}$ accepts $\mathbf{\Psi}$ and she will exercise $\mathbf{\Psi}$ using $\mathbf{K_{Del}}$" in the second message (**[ƛ_2]**), and finally, $\acute{\mathbf{M}}''$ signifies [$\mathbf{\Psi}$**, TS,** $\mathbf{K_{\underline{R}}}$**,** and $\mathbf{K_{Del}}$] in the final message (**[ƛ_3]**), where **TS** signifies the delegation token's time span. Moreover, to mitigate phishing attacks, in ƛ_3, the essential $\mathbf{K_{\underline{R}}^{-1}}$ is used to represent the grantor instead of using the name "$\underline{\mathbf{R}}$" this is because even an attacker succeeded in masquerading as $\underline{\mathbf{R}}$, he cannot delegate the grantor's accountability because he did not know $\mathbf{K_{\underline{R}}^{-1}}$**.** Similarly, $\underset{\cdot}{\bar{\mathbf{R}}}$ is only allowed to execute the set of rights in $\mathbf{\Psi}$ by the approval of the grantor ($\underline{\mathbf{R}}$).

In conclusion, there are quite a few assumptions made based on the referenced papers on delegations' tokens which might not be included in this paper. Therefore, the reader can refer to these articles for a better understanding of some of the conditions imposed based on delegation tokens [21], [23].

B. Initial State Assumptions

The needed initial assumptions are listed below for our accountability analysis. Note that $\underline{\mathbf{R}}$ and $\underset{\cdot}{\bar{\mathbf{R}}}$ represent the Grantor and the Grantee, respectively, as indicated above, whereas the Greek Capital Letter Xi (**Ξ)** is used to represent the assumptions such as $\mathbf{\Xi_1}$, $\mathbf{\Xi_2}$, …, $\mathbf{\Xi_N}$.

[Ξ1]: $\underline{R}$ CanProve ($K_{\underline{R}}$ Authenticates $\underline{R}$);

[Ξ_2]: $\underset{\cdot}{\bar{R}}$ CanProve ($K_{\underset{\cdot}{\bar{R}}}'$ Authenticates $\underset{\cdot}{\bar{R}}$);

[Ξ_3]: $\underset{\cdot}{\bar{R}}$ CanProve (K_{Del} Authenticates $\underset{\cdot}{\bar{R}}$);

[Ξ_4]: $\underset{\cdot}{\bar{R}}$ CanProve ($\underline{R}$ CanExecute Ψ);

[Ξ_5]: $\underline{R}$ CanProve ($\underset{\cdot}{\bar{R}}$ IsTrustedOn (K_{Del} Authenticates $\underset{\cdot}{\bar{R}}$);

[Ξ_6]: $\underline{R}$ CanProve ($K_{\underset{\cdot}{\bar{R}}}'$ Authenticates $\underset{\cdot}{\bar{R}}$);

[Ξ7]: $\underset{\cdot}{\bar{R}}$ CanProve ($K\underline{R}$ Authenticates $\underline{R}$);

This paper denotes that assumptions $\mathbf{\Xi_1}$**,** $\mathbf{\Xi_2}$**,** and $\mathbf{\Xi_3}$**,** to be associated with asymmetric keys, which means that the association of principals to statements can be proved with the help of public-key certificates. Moreover, $\mathbf{\Xi_4}$ assumes that Grantee CanProve Grantor is able to execute the set of rights listed in Ψ**.** However, even though $\underline{R}$ been the grantor is delegating the grantee been $\underset{\cdot}{\bar{R}}$**,** the grantee has to be convinced the delegated rights belong to $\underline{R}$.

Similarly, $\mathbf{\Xi_5}$ is assumed to be trusted during the announcement of its delegation key because he is accountable for the message signed with this key. Lastly, this paper's objective, as mentioned earlier, is not on the authentication of principals but on the delegation. Therefore, the author makes $\mathbf{\Xi_6}$ and $\mathbf{\Xi_7}$ based on the assumption that before the delegation protocol starts, the primary goals of a public key distribution protocol were reached as implemented in the certificate distribution center of the SPX protocol [19].

C. Objectives and Improved Delegation-Based Accountability Protocol

The following denotes the improved protocol message interpretation based on Kailar's notation and the protocol's relevant messages.

1) $\underset{\cdot}{\bar{R}}$ Receives (($\underline{R}$ wishes to delegate to $\underset{\cdot}{\bar{R}}$ accountability for Ψ) SignedWith $K_{\underline{R}}^{-1}$).

2) $\underline{R}$ Receives ((K_{Del}, Authenticates $\underset{\cdot}{\bar{R}}$) SignedWith $K_{\underset{\cdot}{\bar{R}}}'^{-1}$).

3) $\underset{\cdot}{\bar{R}}$ Receives ((delegation of Ψ to $\underset{\cdot}{\bar{R}}'$) SignedWith $K_{\underline{R}}^{-1}$).

Similarly, below are the main Objectives and explanations, which will be used together with the *inference rules* of Kailar logic, the assumptions made, and the protocol messages during the accountability analysis to attain the goals listed below. Thus, this works represents the goals as Greek Capital Letter Pi (Π) such as Π_1, Π_2, … Π_N, and the first goal of our accountability analysis is:

[Π_1]: $\underset{\cdot}{\bar{R}}$ CanProve ($\underset{\cdot}{\bar{R}}$ CanExecute Ψ with K_{Del})

If our analysis can prove the above goal with the application of the new proposed postulate **[Ỹ]**, and the Inference postulate, the results of the analysis can show more general facts that;

$\underset{\cdot}{\bar{R}}'$ CanProve ($\underset{\cdot}{\bar{R}}$ CanExecute Ψ).

Finally, to ensure accountability between the Grantor and the Grantee, the analysis in this paper wants to prove that the Grantor can prove the delegation key "K_{Del}" is used to authenticate the Grantee because $\underline{R}$ cannot be accountable for "*$\underset{\cdot}{\bar{R}}'$ CanExecute Ψ using K_{Del}.*" Therefore, the second goal of this paper's analysis will be as follows;

[Π_2]: R̠ CanProve (K_{Del} Authenticates Ṝ′)

D. Analysis of the Improved Delegation-Based Accountability Protocol

The author starts the delegation accountability analysis by applying the **sign** postulate on **GƆ**$_3$ and **A7** to obtain the following results, which will help us in the next step of the analysis, it is important to note that the sign postulates are represented by $\boldsymbol{\lambda_1, \lambda_2, \ldots, \lambda_N}$.

[λ_1]: Ṝ CanProve (R̠ Says (delegation of Ψ to Ṝ))

Therefore, in attaining the above results, we will use the ***Conjunction (Conj)*** postulate on assumptions $\boldsymbol{\Xi_3}$, $\boldsymbol{\Xi_4}$, and the $\boldsymbol{\lambda_1}$ attained above, the final results after the above process are;

[λ_2]: Ṝ CanProve (R̠ CanExecute Ψ,

R̠ Says (delegation of Ψ to Ṝ),

K_{Del} Authenticates Ṝ)

Finally, we will have to use the *Inference (Inf)* and the [$\ddot{\mathbf{X}}$] postulate on $\boldsymbol{\lambda_2}$ to obtain **[Π_1]**.

[Π_1]: Ṝ CanProve (Ṝ CanExecute Ψ with K_{Del})

Note that at this stage of the analysis, we have proven our first goal as stated above, which means that the grantee can prove he or she is accountable for executing the actions or rights listed in $\boldsymbol{\Psi}$ using the key $\mathbf{K_{Del}}$. Furthermore, now we can use the sign postulate and apply it to **GƆ**$_2$ and $\boldsymbol{\Xi_6}$ to show the results below, which will help us achieve our final goal. Therefore, applying $\boldsymbol{\lambda_2}$ on **GƆ**$_2$ and $\boldsymbol{\Xi_6}$, we have the following;

[λ3]: R̠ CanProve (Ṝ Says (KDel Authenticates Ṝ))

In conclusion, our Π_2 is deduced by Trust postulates using $\boldsymbol{\lambda_3}$ and $\boldsymbol{\Xi_5}$ as the basis. Consequently, we conclude that our analysis shows that the improved protocol achieves its objectives, such as empowering the *Grantor R̠* and the *Grantee Ṝ* to hold each other accountable for their actions made after the protocol. For instance, the *Grantor (R̠)* can prove that the delegation key *K_{Del} authenticates Ṝ*.

VI. Conclusion

The increasing security and privacy threat on the internet has made accountability a significant necessity in almost all electronic commerce transactions. Identifying protocol messages that need to provide accountability assurances during the design of electronic commerce protocols or other internet transaction-related protocols should be regarded with great significance and mainly to avoid disputes among participants in a given transaction. This paper raises the importance of accountability, especially in electronic transactions. Additionally, we introduce in detail a framework to analyze accountability of delegation-based SPX protocol. Delegation allows transfers of a set of rights to another principal to execute, such as from a delegator to a delegate. The result of our study proved that the critical issues of accountability associated with the transferred rights are disregarded or ignored by many. Finally, the paper recommends consideration of accountability during the design of protocols, especially for electronic commerce, in order to prevent possible dispute among participants during a transaction. For future work, the Author intends to explore Kailar's framework to analyze more protocols.

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Analysis of Big Data Storage Tools for Data Lakes based on Apache Hadoop Platform

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***Abstract*—When developing large data processing systems, the question of data storage arises. One of the modern tools for solving this problem is the so-called data lakes. Many implementations of data lakes use Apache Hadoop as a basic platform. Hadoop does not have a default data storage format, which leads to the task of choosing a data format when designing a data processing system. To solve this problem, it is necessary to proceed from the results of the assessment according to several criteria. In turn, experimental evaluation does not always give a complete understanding of the possibilities for working with a particular data storage format. In this case, it is necessary to study the features of the format, its internal structure, recommendations for use, etc. The article describes the features of both widely used data storage formats and the currently gaining popularity.**

Keywords—Big data formats; data lakes; Apache Hadoop; data warehouses

I. Introduction

One of the most important tasks of any systems for data processing is a problem of storing the data received. In traditional approaches, the most popular tools for storing data have been the use of relational databases [1], which represent a convenient interface in the form of SQL for manipulating data.

The growth in the volume of data and the needs of consumers of data processing systems has led to the emergence of the big data concept [2, 3]. Big data concept is based on six aspects such as value, volume, velocity, variety, veracity, and variability [4]. It means that big data can be understood through not only the volume, but also their ability to be sources for generating valuable information and ideas [5].

New concepts have replaced traditional forms of data storage, among which NoSQL [6] solutions and so-called data lakes [7-9]. A data lake is a scalable system for storing and analyzing data retained in their native format and used for knowledge extraction [6]. A data lake can either be designed from scratch or developed on the basis of existing software solutions [8]. Many implementations of data lakes use Apache Hadoop as a basic platform [9].

For data lakes built based on the Apache Hadoop ecosystem, HDFS [10] is used as a basic file system. This file system is cheaper for use than commercial data bases. Using such data warehouse, choosing the right file format is critical [11]. File format determines how information would be stored in HDFS. It is required to take into account that Apache Hadoop and HDFS does not have any default file format. This determined the emergence and use of various data storage formats in HDFS.

Among the most widely known formats used in the Hadoop system are JSON [12], CSV [13], SequenceFile [14], Apache Parquet [15], ORC [16], Apache Avro [17], PBF [18]. However, this list is not exhaustive. Recently, new formats of data storage are gaining popularity, such as Apache Hudi [19], Apache Iceberg [20], Delta Lake [21].

Each of these file formats has own features in file structure. In addition, differences are observed at the level of practical application. Thus, row-oriented formats ensure high writing speed, but column-oriented formats are better for data reading.

A big problem in the performance of platforms for storing and processing data is the time to search and write information, as well as the amount of data occupied. Managing the processing and storage of large amounts of information is a complex process.

In this regard, when building big data storage systems, the problem arises of choosing one or another data storage format. To solve this problem, it is necessary to proceed from the assessment results according to several criteria.

However, testing and experimental evaluation of formats does not always provide a complete understanding of the possibilities for working with a particular data storage format. In this case, it is necessary to study the features of the format, its internal structure, recommendations for use, etc.

The aim of this paper is to analysis the formats used for data storing and processing in data lakes based on Apache Hadoop platform, their features, and possibilities in application for various tasks, such as analytics, streaming, etc. This study is useful when developing a system for processing and storing big data, as it comprehensively explores various tools for storing and processing data in data lakes. In turn, a misunderstanding of the features of the structure and recommendations for the use of tools for storing data can lead to problems at the stage of data processing systems maintenance.

The article describes both well-known and widely used formats for storing big data, as well as new formats that are gaining popularity now.

The paper is organized as follows. In the Background section, the main prerequisites for the emergence of data lakes, as well as the features of the file formats used to store data in data lakes built on the basis of the Hadoop platform will be discussed. Challenges section explores emerging storage trends for building data lakes.

II. Big Data Storage Formats

Relational databases are the traditional way of storing data [22]. One of the obvious disadvantages of this storage method is the need for a strict data structure [23].

In recent years, the direction of development of the so-called data lakes has gained popularity [7–9]. A data lake is a scalable system for storing and analyzing data retained in their native format and used for knowledge extraction [7]. The prerequisites for this were the following factors:

- Growth in the volume of unstructured data, such as the content of web pages, service logs, etc. For these purposes, it is not assumed that there is a common format.
- The need for storing and analyzing large amounts of semi-structured data, such as events from the data bus, unloading from operational databases, etc.
- Development of OLAP technologies and analytics-oriented data storage facilities.
- Development of streaming processing and data transmission.

A data lake can either be designed from scratch or developed on the basis of existing software solutions [8]. Many implementations of data lakes use Apache Hadoop as a basic platform [9]. For such systems, HDFS [10] is used as a basic file system. The traditional way of storing data in HDFS is to create files of various formats.

According to the internal structure of the file, the formats used for working with big data can be divided into the following groups:

- Textual formats: CSV, JSON.
- Hadoop-specific formats: Sequence files.
- Column-oriented formats: Parquet, ORC.
- Row-oriented formats: Avro, PBF.

Each of the groups is focused on solving specific problems. Thus, row-oriented formats ensure high writing speed, but column-oriented formats are better for data reading.

Each data storage format will be discussed below.

A. Textual Formats

JSON (JavaScript object notation) is a textual file format, represented as an object consisting of key-value pairs. The format is commonly used in network communication, especially with the rise of REST-based web services [12]. In recent years, JSON have been becoming popular in documented NoSQL databases [24] such as MongoDB, Couchbase, etc.

In addition, JSON is popular in systems that require data transfer because many programming languages support serialization and deserialization using this format by default. This also applies to streaming data processing systems.

- JSON supports following data types:
- primitive: null, boolean, number, string;
- complex: array, object.

CSV (comma-separated values) is a textual file format presented in the form of a table, the columns of which are separated by a special character (usually a comma). The file may also contain a header containing the names of the columns. Despite its limitations, CSV is a popular choice for data exchange because it supports a wide range of business, consumer and scientific applications [13]. In addition, many batch and streaming systems (e.g. Apache Spark [25]) support this format by default.

B. Hadoop-specific Formats

SequenceFile [14] is a binary format for storing data. The file structure is represented as serialized key-value pairs. The peculiarity of this file is that it was specially developed for the Apache Hadoop ecosystem. The structure allows you to split the file into sections during compression, which provides parallelism in data processing.

SequenceFile is a row-oriented format. The file structure consists of a header followed by one or more entries. The header provides technical fields such as the version number, information about whether the file is compressed, and the file's metadata.

There are three different SequenceFile formats depending on the type of compression.

- no compression;
- record compression – each entry is compressed as it is added to the file;
- block compression – compression is performed when data reaches block size.

C. Column-oriented Formats

Apache Parquet [15] is a binary column-oriented data storage format. The format architecture is based on "definition levels" and "repetition levels". An important part of this format is the presence of metadata that stores basic information about the data in a file, which contributes to faster filtering and data aggregation in analysis tasks.

The file structure is represented by several levels of division:

- row group - row-by-row data splitting into rows for faster reading when working in parallel using the MapReduce algorithm.
- column chunk - data block for a column in a row group. This partition is intended to speed up work with a hard disk - in this case, data is written not by rows, but by columns;
- page - is a conceptually indivisible unit containing meta information and encoded data.

Apache Parquet supports the following data types:

- primitive (int32, int64, int96, float, double);
- complex (byte array, time, maps, lists, etc.);
- logical (boolean).

ORC (Optimized Row Columnar) [16] is a column-oriented format for data storing in Apache Hadoop system. This format is optimized for reading big data streams.

Architecturally, this format is similar to the Apache Parquet format. The format structure is divided into metadata and data itself. Metadata stores statistical and descriptive information, indexes, data partitioning information. The data itself is divided into so-called stripes. Each lane is an atomic unit for distributed data manipulation.

ORC supports a full set of types, including complex types (structures, lists, maps, and unions).

D. *Row-oriented Formats*

Apache Avro [15] is row-oriented format for data storing widely used for data serializing. Apache Avro stores the schema in an implementation independent JSON format making it easier to read and interpret by programs. The Avro file consists of a header and data blocks. The header contains file metadata containing a schema and a 16-byte random number marking the file. For data blocks, Avro can use a compact binary encoding or JSON format, convenient for debugging.

Unlike many other Big Data formats, Avro supports schema evolution by handling schema changes by skipping, adding, or modifying individual fields. Avro is not a strongly typed format: the type of each field is stored in the metadata section along with the schema. This means that no prior knowledge of the schema is required to read the serialized information.

Apache Avro supports following data types:

- primitive (null, Boolean, int, long, float, double, string, bytes, fixed);
- complex (union, record, enum, array, map);
- logical (decimal, date, time, timestamp, uuid).

PBF (Protocolbuffer Binary Format) [18] is row-oriented format. A format contains a header followed by a sequence of data blocks. The structure of the format is intended to allow random-access to the file content skipping unwanted data.

The format contains a repeating sequence of the following parts:

- the number presenting the length of the BlobHeader message in network byte order;
- serialized BlobHeader message;
- serialized Blob message.

One of the features of the format is that when serializing integers, it defaults to variable length format, which takes up less space for small positive numbers. However, the format adds the field number and its type to the binary stream, which increases the total size.

PBF supports following data types:

- primitive (bool, int32, int64, uint32, uint64, float, double, string, bytes, etc.);
- complex (oneof, message, enum, array, map);
- logical (date, time, timestamp).

E. *Analysis of Data Storage Formats*

Within the framework of this study, an analysis of the main characteristics of the previously described formats was carried out. Comparative characteristics of the formats are presented in the Table I.

This section may be divided by subheadings. It should provide a concise and precise description of what data is contained, which format, how to read and interpret the data. E.g., for tabular data a note about what's contained in each column of the data table.

TABLE I. COMPARATIVE CHARACTERISTICS OF THE FORMATS

	avro	**csv**	**json**	**orc**	**parquet**	**pbf**	**sequence**
Platform independence	+	+	+	-	-	+	-
Changeability	-	+	+	-	-	-	-
Complex structures support	+	-	+	+	+	+	-
Compliance with ACID	-	-	-	+	-	-	-
Format type	row-oriented	text	text	column-oriented	column-oriented	row-oriented	row-oriented
Compression support	+	-	-	+	+	+	+
Metadata presence	-	-	-	+	+	-	-
Schema integration	+	-	+	-	+	-	-
Readability	-	+	+	-	-	-	-
Schema evolution	+	-	-	-	+	+	
Usability for streaming systems	+	+	+	-	-	+	-

Table II summarizes the main advantages and disadvantages of each studied data storage format.

In addition, other studies have been explored aimed at choosing a format for various purposes.

In [26], the Apache Parquet and Apache Avro formats are compared in terms of performance, but in this study, there is no justification for choosing this particular alternative. The study proceeds from an experimental assessment of two formats in the absence of a specific task of choosing alternatives. The authors of [27] pursue the goal of finding an alternative for the WARC format when developing web services. Apache Parquet and Apache Avro are also alternatives in this study. The author in [28] offers extensive research on various data storage formats for the analytical task in bioinformatics. This article provides an assessment of all the formats described here. Apache Parquet and ORC were chosen as the most suitable format. The authors also give recommendations on the use of a particular format. Specifically, when running multiple queries, it is recommended to use Apache Parquet, while ORC should not be used [28]. Research [29] is aimed at evaluating the Avro and Parquet formats when performing data queries. The research results are recommendations on the use of each format for specific tasks. [30] is a comprehensive study of the Apache Parquet and ORC formats. Both formats are column-oriented and share similar characteristics and properties. The study carried out a number of experiments focused on the applied properties of each format.

The study [31] developed a methodology for analyzing data storage formats based on comparative analysis, experimental evaluation and a mathematical model for choosing an alternative. For the experimental evaluation, Apache Spark [24] framework was used, which is one of the most popular tools for analyzing data in the Apache Hadoop system.

TABLE II. ADVANTAGES AND DISADVANTAGES OF BIG DATA STORAGE FORMATS

Format	Advantages	Disadvantages
csv	Readable and manually editable; Provides a simple table layout; Can be handled by almost all existing applications; Compact.	Doesn't support complex data structures; Allows to work with flat data; There is no support for column types; There is no standard way to represent binary data; Problems with CSV import (for example, there is no difference between NULL and empty string); Poor support for special characters; Lack of a universal standard.
json	A readable format that allows to work with it without the use of special software; Support for a hierarchical structure, which allows reading a complete set of data; Supported by many programming languages and default data tools. Support for complex types such as arrays and objects. Data schema support.	Format consumes large amount of memory due to repeatable field names; Poor support for special characters; Less compact compared to more binary formats.
avro	High speed of information recording; Fast reading of all fields of the record; JSON data schema provides support for many programming languages and facilitates debugging during development. The availability of extensive capabilities for describing objects and events, including creating your own data schemas, Compatibility with previous versions as data evolves over time.	Reduced speed of information reading, since it is required to read all fields of the record; Lower performance when performing selective queries; Higher consumption of disk space for data storage.
pbf	Compressed data storage format; Self-described data storage format;	Small community, which makes it difficult to develop in case of problems with the format; Storing data type information for each stored value.
parquet	Column-oriented format allows to allows you to significantly speed up the work of the analyst. Efficient storage in terms of space occupied. It provides fast reading experience.	Doesn't support changing data; Does not support schema evolution; Transactions are not supported; No possibility of using in streaming systems; Loss of information due to loss of metadata.
orc	Indexing that speeds up I/O operations; The presence of metadata to facilitate the optimal execution of queries; Transactional support.	Doesn't support schema evolution; Loss of information due to loss of metadata; Transactionality occurs by adding new files.
sequence	Compact format; There are 2 types of file compression - at the record level and at the block level; The ability to parallelize tasks by independently unpacking and using different portions of the same file; Can act as a container for many small files	Lack of multilingual support - this format is specific to the Apache Hadoop ecosystem, which determines the use of only the Java API. Doesn't support complex structures; Doesn't support column types.

A number of disadvantages of the described formats for storing big data have been identified. The main ones are the following:

- Failure to comply with the requirements of the “General Data Protection Regulation” [32]. This regulation defines the human right to "oblivion". In this case, the storage tools must be able to delete the record. In the formats described earlier, only text formats have the ability to delete one record. Other formats require deleting the entire file and writing a new one.
- The need for a transactional data record. Of the above formats, only the ORC format has this property, which requires the addition of delta files to update records.
- Building data storages on dimensional model;
- Requirements for schema enforcement.

The conventionally described data storage formats can be divided into groups containing alternative formats, depending on the tasks assigned to these formats when they are used in big data processing systems.

Accessibility to the data described formats can be divided into the following groups:

- changeable (JSON, CSV);
- unchangeable (Parquet, Avro, ORC, SequenceFile, PBF).

The following groups are distinguished by the internal structure of the file:

- textual (JSON, CSV);
- column-oriented (Parquet, ORC);
- row-oriented (Avro, PBF, SequenceFile).

According to their application in tasks of processing and storing data in big data systems, the formats can be divided into the following groups:

- formats for data streaming (JSON, CSV, Avro, PBF);
- formats for data storing (Parquet, ORC, SequenceFile).

III. Challenges

The limitations of the previously described formats have determined further research and development in the storage of information in data lakes. Among the most well-known emerging big data storage facilities are the following projects: Apache Hudi [19], Delta Lake [20], Apache Iceberg [21].

A. Apache Hudi

Apache Hudi (Hadoop Upserts Deletes Incrementals) [19] is a framework developed for managing big data storage in distributed file systems such as cloud storage, HDFS and other storage combined with Hadoop FileSystem. A distinctive feature of this system is a support of transactional operations (ACID).

Changes to data tables are achieved in two ways: copy on write and merge on read.

- Copy on write: Data is stored in the Parquet file format and each update creates a new version of the file at write time. This storage type is most suitable for read-intensive batch downloads.
- Merge on Read: The data is stored as a combination of the Parquet and Avro file formats. Updates are logged in delta files. This type of storage is better suited for streaming write-intensive workloads.

Data queries are divided into following types:

- Snapshot: The last snapshot of the table as of this commit action. For “Merge on Read” tables, the snapshot query will merge base files and delta files on the fly, resulting in latency.
- Incremental: changes in the table since commit.
- Read-Optimized: The last snapshot of the table at the time of this commit action. For “Merge On Read” tables, read-optimized queries return a view that contains only the data in the underlying files, without merging delta files.

Recent privacy regulations such as the GDPR [32] require companies to be able to perform record-level updates and deletions in order to satisfy the human right to be forgotten. With support for deletes in Hudi datasets, the process of updating or deleting information for a specific user or over a period of time is greatly simplified.

B. Apache Iceberg

Apache Iceberg [20] - is a tabular format for storing tables larger than a petabyte. Iceberg was designed from the ground up for use in the cloud, and the key was to address the various data consistency and performance issues that Hive [33] suffers from when used with data residing in S3 [34]. Iceberg defines how to manage large analytic spreadsheets using immutable file formats such as Parquet, Avro, and ORC.

All information is stored in several different files:

1) Snapshot metadata file contains metadata about the table, such as the table schema, section specification, and the path to the list of manifests.

2) Manifest List contains an entry for each manifest file associated with the snapshot.

3) Manifest file contains a list of paths to related data files.

4) Data file is a physical data file written in formats such as Parquet, ORC, and others.

Apache Iceberg has the following benefits:

1) Lack of "dirty reading" [35]. The use of a snapshot guarantees isolated reading and writing. Readers will always see a consistent version of the data without having to lock the table. Writers work in isolation without affecting the live table.

2) Performance benefits. Instead of listing O(n) partitions in a table during scheduling, Iceberg performs O(1).

3) Data schema evolution. Iceberg ensures that schema changes are independent and have no side effects.

4) Evolution of partitions. Through the implementation of hidden partitioning, Iceberg is also able to propose an evolution in the partitioning specification. This means that the project provides the ability to change the granularity or the column that is split without breaking the table.

5) Support for the query engine. Iceberg is supported by the Apache Spark project, that is, data can be read and written using Spark DataFrames [25], and also read using SparkSQL [25].

C. Delta Lake

Delta Lake is a storage layer for improving the reliability of data lakes [36–38]. Delta Lake can operate on the basis of implemented data lakes using Apache Hadoop [11], Amazon S3 [32] or Azure Data Lake Storage [39].

Delta Lake is characterized by the following properties:

- Support for ACID transactions. Delta Lake Brings ACID Transactions to Data Lakes for Serializability and Highest Isolation.
- Scalable metadata processing. Delta Lake processes metadata using the distributed computing power of Apache Spark.
- Data versioning. Delta Lake provides snapshots of data, allowing you to access and downgrade to earlier versions.
- Open format - all data in Delta Lake is stored in Apache Parquet columnar format, which allows you to efficiently compress and encode data.
- Unified batch and streaming source and consumer in one.
- Evolution of the scheme. Delta Lake allows for table schema changes that can be applied automatically.

IV. Conclusion

Today, data lakes are the most advanced area of big data processing and analysis. In recent years, many platforms have emerged that provide the ability to build data lakes. This study explored the storage tools provided for building data lakes based on the Apache Hadoop platform.

As part of the study, we reviewed the main formats for storing big data in data lakes. Three groups of big data storage formats have been studied: textual, row-oriented, column-oriented. Each group describes the alternatives among the formats. The distinctive characteristics of each format are presented, including features of the internal file structure, supported data types, recommendations for use; highlighted the advantages and disadvantages of each format.

A comparative analysis of the most popular formats for storing big data has been carried out. The studies aimed at identifying the effectiveness of a particular data storage format in relation to the task have been analyzed. The main advantages and disadvantages of the most popular big data storage formats are highlighted.

During the study, the main prerequisites for further research and development of tools for storing big data in the construction of data lakes were studied and determined. One of the main reasons for further research was the requirement for the confidentiality of personal data. This requirement determines the ability to delete a record from the data store. In addition, one of the obvious disadvantages of data storage formats is the lack of transactional operations.

New trends in the field of building data warehouses in the context of data lake architectures are considered; highlighted new requirements for the development of data warehouses. A review of modern tools that meet new requirements is carried out. Their distinctive characteristics and advantages of use have been highlighted.

The analysis of the main properties of data storage formats, their structure and application features, as well as the study of modern trends in the storage and processing of big data in data lakes are necessary for further experimental evaluation of these tools, as well as the development of a methodology for choosing a format that meets system requirements when developing a system for processing big data. These tasks are further objectives of the authors' research.

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An IoT-based Coastal Recreational Suitability System using Effective Messaging Protocol

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***Abstract*—Coastal recreational activities are one of the main attractions for local public beachgoers and overseas tourists. The accessibility to better-quality coastal water will enhance safety and public health awareness when the information is available. Existing platforms showing the risk of whether a beach is suitable for public recreational use is less available in Malaysia. The Internet of Things (IoT) based system design specifically for coastal recreational suitability may differ from the existing configuration depending on the environment and requirements. This paper reports the design and implementation of an IoT-based system to capture the coastal environmental data and recommend recreational suitability. The system captures sensor data, store it in a database and displays the result using a dashboard. The variable data include the temperature, humidity, rain, pH, turbidity, oxidation-reduction potential (ORP), and total dissolved solids (TDS) in a coastal area. The hardware used in the design is the development boards such as Raspberry Pi, Arduino Uno, and ESP32 controller. The system is developed using PHP, MySQL, and Apache Web Server and can be accessed online at https://ipantai.xyz. When using Message Queuing Telemetry Transport (MQTT) as the effective messaging protocol and HiveMQ broker, the result has shown improvement for message size, throughput, and power consumption. The further potential of an IoT-based system is to bring value for coastal management and serve as a powerful tool to determine whether the coastal area is suitable for the public to access water recreational activities.**

Keywords*—Coastal recreational; internet of things; message queuing telemetry transport; sensor; water quality

I. Introduction

Most countries in the world are surrounded by the ocean. The length of coastlines in the world is estimated at 1.16 million kilometres. Malaysia has about 4,800 kilometres of coastline comprising two distinctly different physical formations, namely the mangrove-fringed mudflats and sandy beaches. The coastlines are about equally divided between mud coast and sandy beaches. At least 50% of the adult population in the world visits the public water areas such as beaches, islands, etc. for recreational purposes [1]. Beachgoers rarely receive water quality information, whether the waters are suitable for recreational activity or vice versa. Poor water quality (such as microbial contamination) in coastal water poses a public health threat due to waterborne diseases. The risk of exposure to microbial contamination can be reduced by informing beachgoers in advance about the water quality. Recreational water activities improve when the water has better quality [2], [3] but users do not always recognise poor water quality or its associated health risks [1]. Coastal recreational activities are rapid development of economy and urbanisation can promise highly to expose to nearest water resources including the coastal area that ultimately embraces poor water quality severely by time excluding the existing harmful microbiology in the coastal ocean area. Therefore, understanding the problems and trends of water quality are crucial and significant to determine the water quality at a specific coastal area, formulate prevention and control, also to educate the public in terms of health risk by establishing related public information and regulation at the coastal recreational area.

In the 21st century, the accessibility to data and information is known at the fingertip. The Internet of Things (IoT) has become the basis of digital transformation and automation in delivering new ideas and service offerings to improve the way we live, work, and entertain ourselves [4], [5]. IoT is foreseen as a technology enabler in various cases. This paper reports the design and development of an IoT-based system for coastal recreational suitability. The system serves as a means to capture and monitoring for beach water quality. The system can be accessed by the public and potentially provide an initial awareness of clean coastlines. The coastal recreational area effectively contributes not just to public attraction as part of a tourism attraction but also contributes to the comprehensive economic driver for the state [6]. To understand and propose a solution to overcome the issue, this paper intends to explore an integrated approach suitable for coastal recreational suitability. The objectives are to:

- Design and develop an IoT-based system for coastal recreational suitability systems.
- Implement an IoT-based system to suit the requirements for capturing, storing, and reporting coastal environment data.

The paper is organised into several sections. The first section introduces the research idea. The next section presents the related work in the area. Followed by methodology for system development and experiment set up. Afterwards, the

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paper discusses the results and finally summarise them with a conclusion and recommendation for future work.

II. Related Work

A. Internet of Things (IoT)

IoT can be described as "an interconnection of machines and devices through the internet allowing the creation of data that can shed light on analytic performance and support new technologies" [7]. Another author [8] describe IoT as "a system of a physical object having independent communication among them." Researcher [9] defines IoT as "inter-net-connected embedded systems that can be upgraded and adapted to changing needs on-demand, useful information can be immediately collected from remote geographic areas, and fault diagnosis and system restart can be made more efficient and cost-effective by not having to send out technicians to remote places". Throughout the years, IoT is maturing and continues as one of the exciting concepts in the IT world [10]. Over the last decade, the term IoT has attracted attention by projecting the vision of a global infrastructure of networked physical objects, enabling any time and place connectivity for anything and not just for anyone through the internet [11], [12].

B. IoT in Coastal Research

Some research has been undertaken on coastal recreation using IoT. Be Right Beach (BRB) was developed consisting of a sensor network with a UV sensor, thermometer, humidity sensor and a camera for crowdedness estimation [13]. The data was collected by a cloud platform that provides useful information about the beaches and suggestions where to go based on user preferences like weather, crowdedness, time of travel etc. Another research example was blockchain innovation and IoT will help all users to get involved together in economic activities [14]. Next, researchers found out that the design, development, and deployment of an IoT-based marine environment monitoring and protection system is needed to address some critical issues including autonomy, adaptability, scalability, simplicity, and self-healing [15]. Another researcher [16] suggests application layer is to provide smart application services to meet user needs. In IoT-based marine environments, the application layer covers water quality monitoring, coral reef monitoring, marine (either offshore or deep-sea), fish farm monitoring and wave.

C. Water Quality

The context of water quality has been recognised to be the main highlight that requires important information about public health, environmental concern, and the quality of beach water for public usage. Over the years, coastal water was habitually exposed to anthropogenic and industrial pollution that led to negative consequences to public health and recreational activities [17]. In general, water quality is described as the assessment of sanitary and microbial water quality collectively. The results of the assessment should give a proper clarification about the water quality around the investigated beaches to inform the public, provide on-site guidance and information to the public relative to the safety aspect, assist and promote effective recreational management and formulate regulatory compliance based on the recreational area. Fig. 1 shows the classification matrix of water quality assessment.

D. Recreational Suitability

The detection of faecal contamination at the coastal beaches is subjected to extensive water quality that includes wastewater discharge, industrial waste over and surface runoff. As a result, the suitability of recreational areas is as crucial as the conservation of recreational areas by providing informative and presentable data about water quality trends in the coastal area. One of the recreational suitability assessments is from the Suitability for Recreational Grade (SFRG) [17]. The grading for the recreational suitability is determined by SFRG via the relationship between Microbiological Assessment Category (MAC) and Sanitary Inspection Category (SIC) [17]. Based on the recreational suitability assessment from SFRG via the relationship between the MAC and SIC, proper recreational management will be implemented to measure proper risk management action and formulate legal regulation before the public safety at the recreational area. There are four major field interventions which are compliance and enforcement control and abatement technology, public awareness and information and public health advice and interventions [17]. In this research outlining a better water quality assessment system is crucial to give better guidelines to formulate legal regulation and action plans based on the data generated by the water quality system used at the recreational area.

There has been less research conducted in IoT for coastal recreational suitability. Previous research focuses on environmental water quality using IoT. Similar research applies IoT devices to monitor beaches and crowd detection [13]. Several research reviews on [18] LoRaWAN implementation as an effective for IoT-based monitoring systems with a frequency below 1GHz which and some using GSM and Thingspeak [19]. In this research, we look at the IoT protocols specifically the IoT design for coastal recreational suitability using Message Queueing Telemetry Transport (MQTT) protocol.

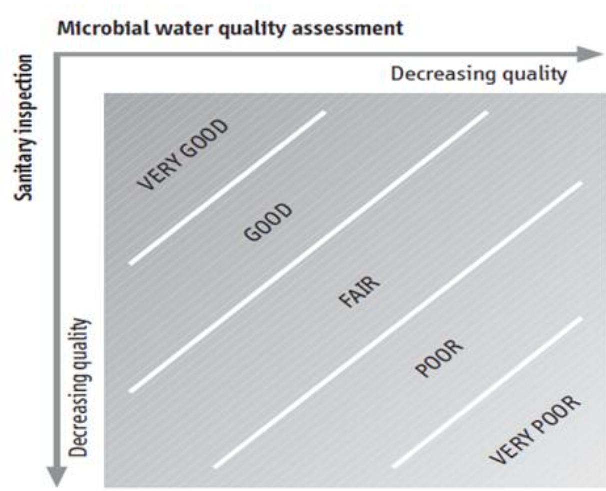

Fig. 1. Classification Matrix of Water Quality Assessment [17].

III. Methodology

A. System Development

In this project, the prototyping method is selected as the approach for system development. A prototype is a software model and through the prototype interaction, users can understand the desired system better. The prototyping method works best in situations where the requirement of the project is unknown. In addition to that, it is a method of iterative, trial, and error that takes place between the system developer and the client.

The advantages of using prototype methodology are:

- It will be easier for the clients to understand the design of the project.
- Real-time monitoring and continuous client-developer interaction assist to build a good relationship.
- Risk factors are easily identified along with steps to mitigate the risk factor.
- Developer can get any input from a client earlier in the development cycle and save time.

In this research, the steps involved in prototyping methodology in Fig. 2 are described.

1) Requirement analysis and information gathering: The first step of prototype methodology involves understanding the very basic requirements of the product, particularly about the user interface. It is possible at this point to neglect the problem in IoT and the messaging protocol that has been developed.

2) System design: The next step is the design the system. As this project must create a web-based system as it is included in client requirements, there need to use an HTTP protocol that relates to a database and world wide web (WWW). To integrate the MQTT protocol in a web-based system, Socket is needed and there is also a need for a Platform as a Service (PaaS) in the computing model. Heroku is used because this platform equips us with a ready runtime environment and application servers. Heroku will be designed as a medium (server) to create a connection to the MQTT broker so it can subscribe to the message from the broker itself. Every browser will request an HTTP upgrade so they can receive the real-time data using SocketIO. The sensor is hardware that is being chosen to measure certain parameters such as humidity, temperature, turbidity, and pH.

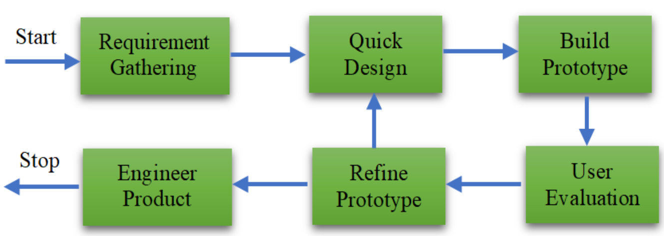

Fig. 2. Prototyping Model.

- HiveMQ

The research proposes the cloud HiveMQ as a broker. The reason for using the cloud was because it is cost-effective and lightweight. The setup for coastal recreational involves many locations, a centralised broker is needed in Fig. 3, and a cloud broker is appropriate. HiveMQ cost is free for a certain limit and suitable for a prototype project. The sensor will publish the data to the HiveMQ broker, and it will publish the message to the client who subscribes to it. Since MQTT are bidirectional communication, it can subscribe and publish at the same time.

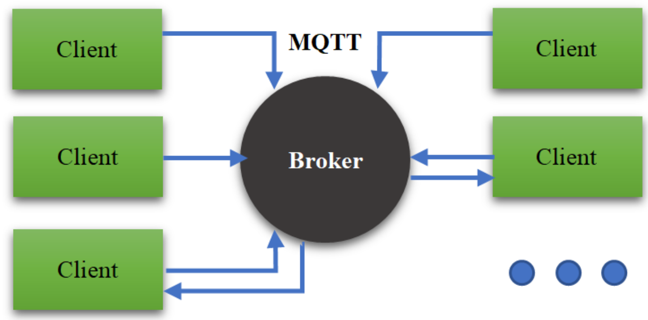

Fig. 3. MQTT Architecture.

- Socket.IO

Socket.IO is a JavaScript library for real-time web applications. It enables real-time, bi-directional communication between web clients and servers. It has two parts: a client-side library that runs in the browser, and a server-side library for Node.js. Both components have a nearly identical API.

Since the project needs to communicate with a broker, socket io can communicate with the MQTT broker and is suitable for this project. Socket.IO primarily uses the WebSocket protocol with polling as a fallback option while providing the same interface. Although it can be used as simply a wrapper for WebSocket, it provides many more features, including broadcasting to multiple sockets, storing data associated with each client, and asynchronous I/O. Socket.IO provides the ability to implement real-time analytics, binary streaming, instant messaging, and document collaboration.

- Apache (HTTP)

Since MQTT does not have a database feature, using the HTTP protocol, it becomes possible to store the data. For the first process of HTTP, the sensor collects the data and transfers it to the Raspberry Pi. The Raspberry Pi, which acts as a web server and uses as a local host for the initial prototype. The sensor is connected to Arduino and Raspberry Pi. The port is going to use port 80. Fig. 4 shows how the HTTP protocol works initially started when a client requested a packet. Send the HTTP header using the TCP/IP protocol and the webserver is decoding, creating the header and formatting data before sending the HTTP response header back to the client.

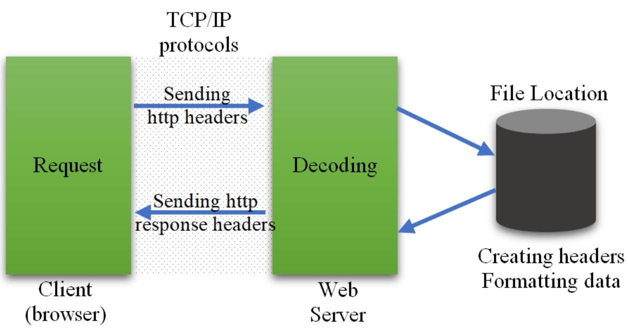

Fig. 4. HTTP Architecture.

3) Developing initial prototype: In this step, the initial prototype is created, demonstrating the basic requirements, and providing user interfaces. It will implement the MQTT protocol with HiveMQ as a cloud broker. Then it will be connected to the Socket IO server that will subscribe to HiveMQ data. Once it gets the data, it will broadcast the message to the client whenever connected to the server. The initial prototype has an explore module that will retrieve the MQTT data in real-time on a webpage. This initial prototype will be presented to the client for client evaluation.

4) Client evaluation: The next step is the client initial evaluation. In this step, the proposed system will be presented to the client for an initial evaluation. The user will verify the function created and it will tally with the client requirement itself. It will help to determine the strength and weakness of the coastal recreational system. Comments and suggestions will be collected from the client and provided to the developer.

5) Refining prototype: In this phase, if the client is not satisfied with the current prototype, the prototype must be improved according to feedback and suggestions from the client. For example, every time was adding new function and module, the user will verify and check the requirement. For example, in this system development, the first module been created are explore module, then the home page module, login/signup module, sensor entry module and sensor reading module. This phase will not be completed until all the client specified requirements have been met. Once the client is pleased with the existing prototype, based on the approved final prototype, a final system is produced.

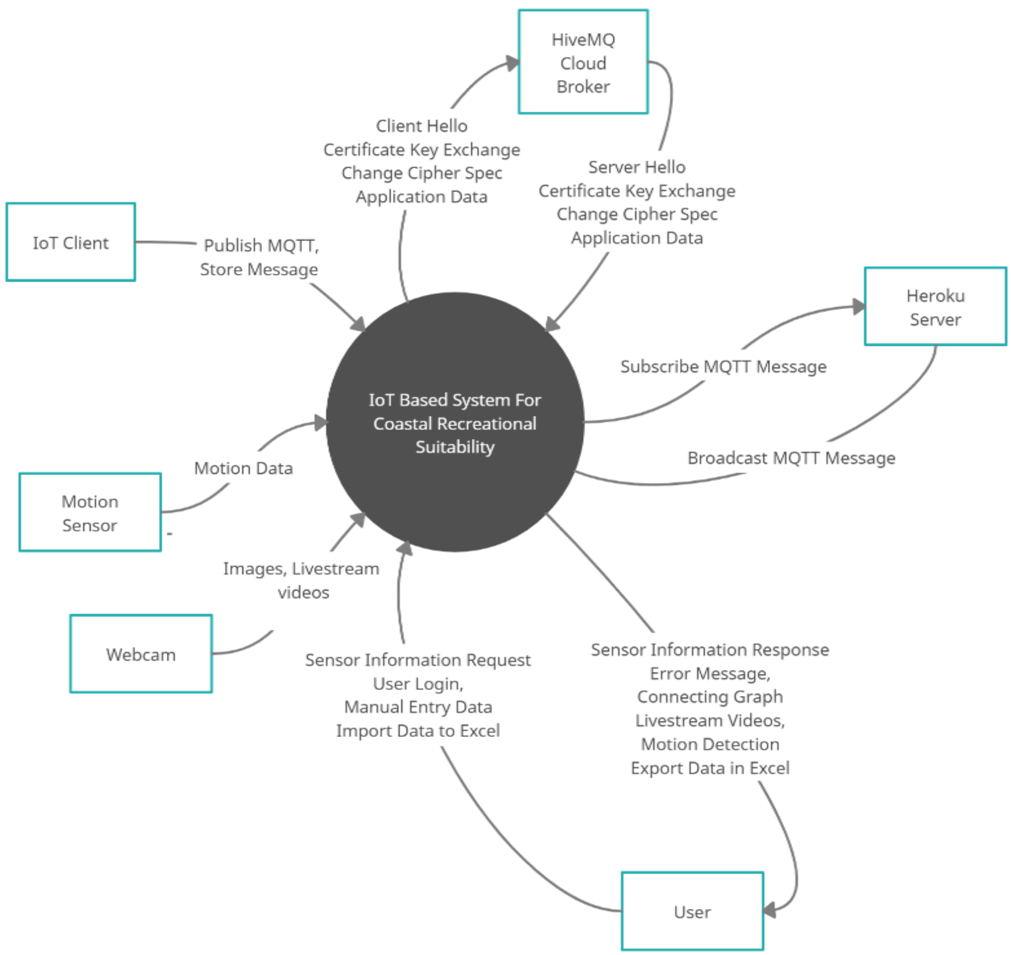

Fig. 5. Context Diagram IoT based Coastal Recreational Suitability System.

6) Implementation and maintenance: Once the final system is developed based on the final prototype, it is thoroughly tested and deployed to production. The system undergoes routine maintenance to minimising downtime and prevent large-scale failures. For example, there is a need to check the sensor onside rather than remote access periodically and to make sure the sensor is cleaned and no obstructions. The system was also tested on a web-based system by checking on Cloudflare to see if there are any attacks on the webserver.

B. Network Design

In this project, three locations are being presented. The system displays based on single locations. For example, the ODEC beach is shown in Fig. 6. These single locations are connected to the HiveMQ cloud broker to publish the message. Socket IO is implemented, and it subscribes to the messages from the HiveMQ broker. Furthermore, SocketIO will publish a broadcast message to every connected client that requests to view the data. Clients that view the data must request io.emit that has been applied on server ipantai via JavaScript. The JavaScript will automatically emit socket io to the server to make a TCP connection via SocketIO. If the connection is successful, every message transmitted by the sensor will be broadcast by the socket io server to the client.

IV. System Implementation

System analysis is gathering and interpreting data to recognise the problems and decomposition into its component. In this phase, the requirements and functionality of this project are determined. The technique used to conduct this analysis is to compare the benchmark with another similar project that uses MQTT with different parameters. Parameter involved for comparison is the message size of MQTT, throughput, and power consumption. After the process of data gathering and comparison, a prototype is developed. Some features in the existing system are based on interviews with stakeholders which are new and unique. Fig. 5 shows the context diagram of the IoT Based System for Coastal Recreational Suitability with six entities which are IoT Client, HiveMQ Cloud Broker, Heroku Server, Motion Sensor, Webcam and User.

Fig. 7 shows a use case diagram of this system works as there are 16 uses cases for this system. For the MQTT part, only five uses case is involved while the remaining 11 are from client requirements. In this use case, three core parts will have their function such as HiveMQ Broker, Heroku Server and ipantai Webserver.

Fig. 8, 9, 10 and 11 show the user interface for the Coastal Recreational Suitability System. The system can be accessed at https://ipantai.xyz.

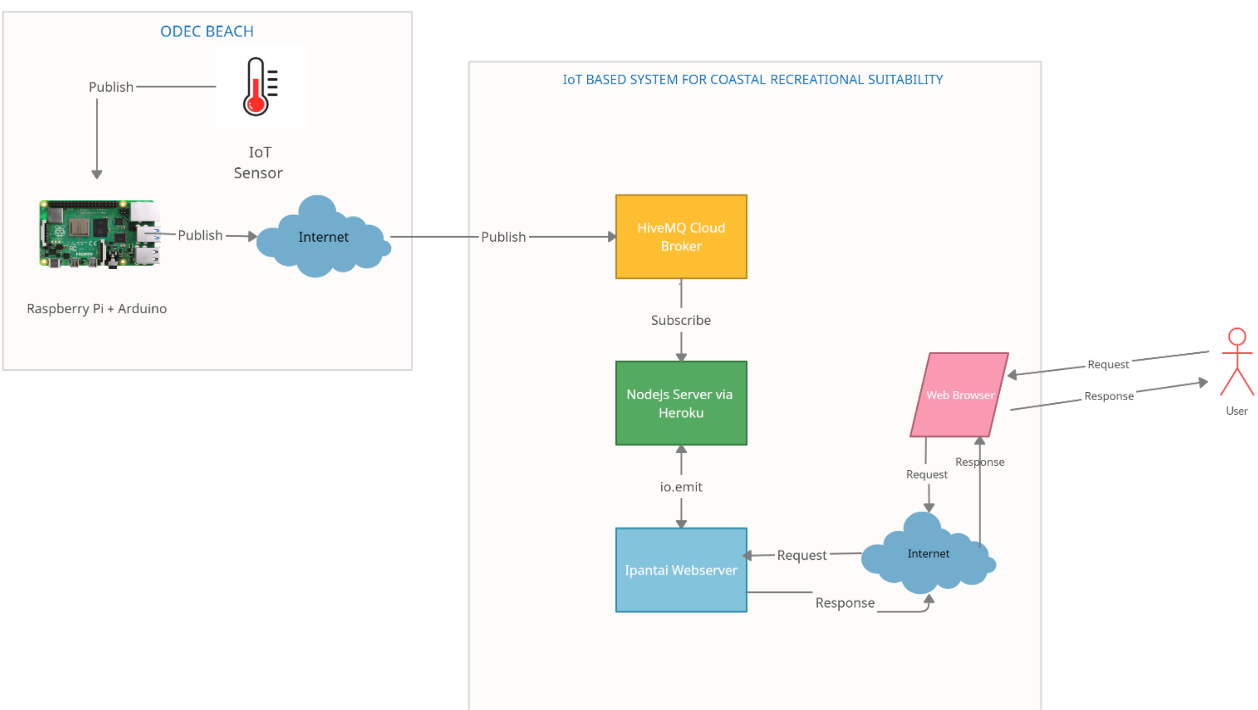

Fig. 6. The Network Design.

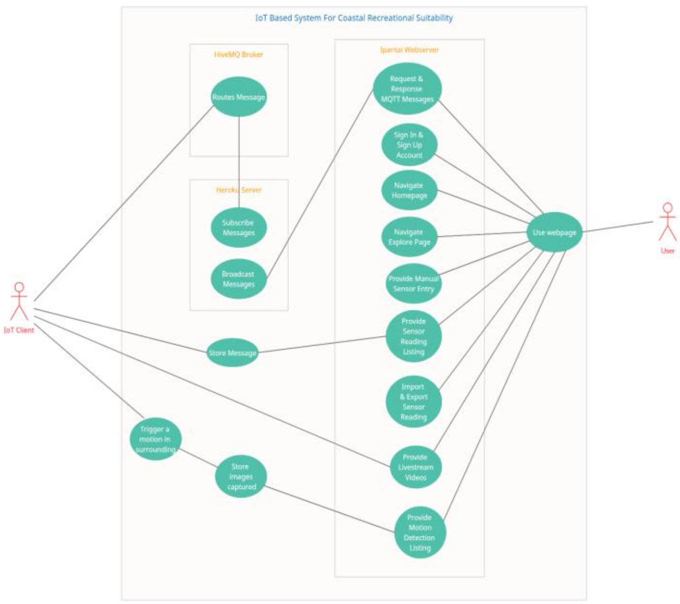

Fig. 7. The use Case.

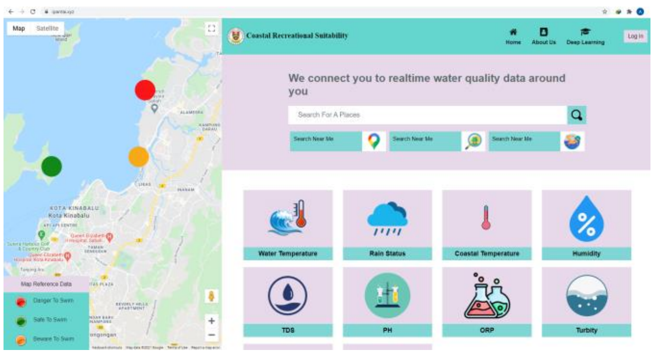

Fig. 8. The Main Page of the Coastal Recreational Suitability System.

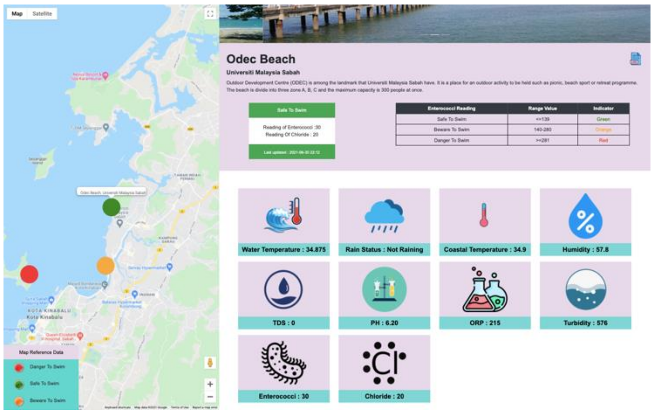

Fig. 9. The Page of Specific Beaches showing the Variable Data.

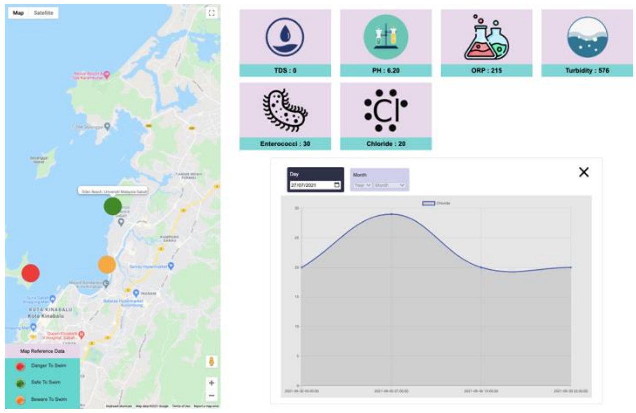

Fig. 10. The Page showing the Graph Representation of a Specific Variable.

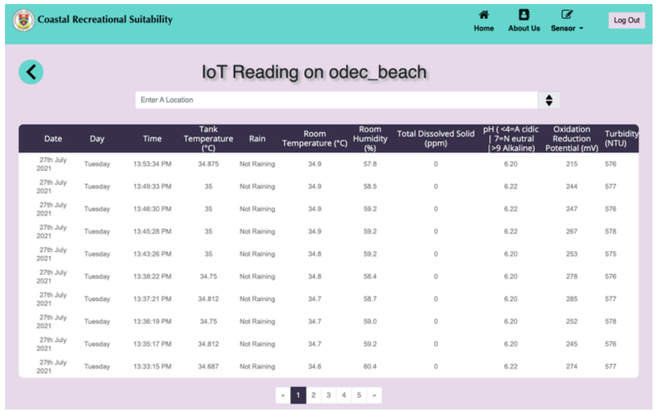

Fig. 11. The Page showing the IoT Readings of a Specific Beach.

V. Result and Discussion

A. Message Size

- Client Publish (Multi-Parameter)

Experiments are conducted to measure MQTT size for full system parameter message size. The script is run in Raspberry Pi that will publish the MQTT message to the broker. The python script will run for looping every second to transmit the message to the broker. The information is processed and can be viewed by subscribing to the message. Fig. 12 shows a script implemented on Raspberry Pi to publish a message to a broker.

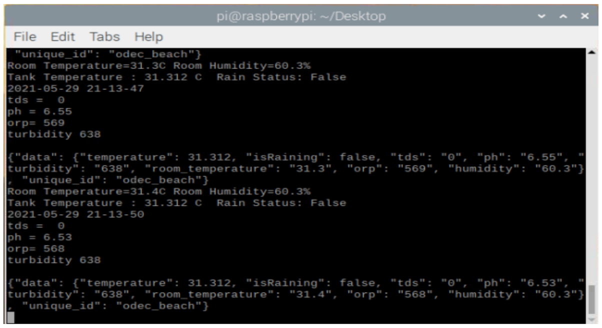

Fig. 12. Publish Message to the Broker.

Fig. 13 shows packets captured by Wireshark during transmission. It shows that the cloud broker used is HiveMQ are using Transport Layer Security V1.2 and it was captured using Wireshark. Before that, an MQTT broker is a server that receives all messages from the clients and then routes the messages to the appropriate destination clients. An MQTT client is any device (from a microcontroller up to a fully-fledged server) that runs an MQTT library and connects to an MQTT broker over a network. From a client to connect to a broker, it must run the TLSV1.2 encryption protocol to gain access with the MQTT broker. Fig. 13 also shows HiveMQ connections are in port 8883 which are more secured than 1883 because SSL will verify that the connection is encrypted using a certificate belonging to the domain name that you were trying to connect to. The two ends will also encrypt all traffic so that an observing party will be unable to eavesdrop. Without SSL IoT devices become vulnerable to a malicious broker impersonating the one you want to connect to. It is also possible that a third party might tamper with the data received. And an eavesdropper might attacker could see MQTT username and password.

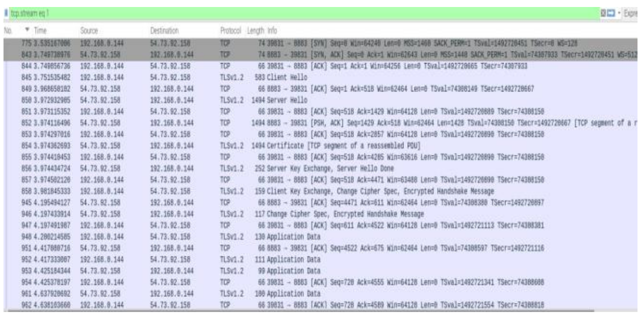

Fig. 13. Wireshark Packet Summary.

From observation has been made using Wireshark found total frame lengths are 297 bytes. Layer 1(Ethernet Frame) size is 14 bytes which contain source and destination IP addresses. Layer 2 (IP header) contains 20 bytes, Layer 3(TCP header) contains 32 bytes, Layer 4 (SSL Header) are 5 bytes. So, the total header involves 71 bytes. The encrypted application data contain 226 bytes per message transmitted. With a sum of 226 bytes and the header will contain exactly 297 bytes.

The data on encrypted applications contain parameters about Coastal Temperature, Humidity, Water Temperature, Rain Status, TDS, pH, ORP and turbidity and unique id(location). The data are sent using JSON format for example: {"data": {"temperature": "33.187", "isRaining": false, "tds": "0", "ph": "6.10", "turbidity": "576", "room_temperature": "35.2", "orp": "310", "humidity": "51.8"}, "unique_id": "odec_beach"}. To prove by combining all the parameters on a single packet could save bandwidth is by comparing the single message experiment on the next part.

- Client Publish (Single Parameter)

The next experiment uses a single parameter to send a message from the client to the broker. From the observation shown in Fig. 14, a single message packet contains a total of 159 bytes that contain ph value and identifier of location. For example, "data": {"ph": "6.48"}, {"unique_id": "odec_beach"}. Layer 1 (Ethernet Frame) size is 14 bytes which contain source and destination IP addresses. Layer 2 (IP header) contains 20 bytes, Layer 3(TCP header) contains 32 bytes, Layer 4 (SSL Header contain 5 bytes for header and 88 bytes for the application data. In comparison, the header between single and multi-parameter are the same but has a huge difference on application data. Using multi-message that only contain 226 bytes from an average of 28.25 bytes per parameter. Thus, it shows three times better for saving network consumption and reducing complexity in MQTT system design.

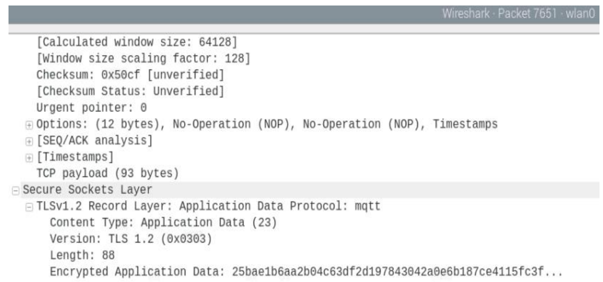

Fig. 14. Single Packet Parameter.

B. Throughput

Testing MQTT message throughput is important for an IoT application. It is also important to identify the maximum message throughput a single MQTT broker instance, as well as an elastically scaling MQTT broker cluster, can support without service degradation. This will help with capacity planning and can ensure deployment scale when the increase in usage.

The experiments are conducted to measure the throughput using ntopng installed on Raspberry Pi. It provides a web GUI to access accurate monitoring data. It provides detailed views on active hosts, flows, IP addresses, Mac addresses, Autonomous Systems, and throughput. From that, it can easily identify MQTT brokers and Pi. Throughput is how much information gets delivered in a certain amount of time. Most of the time network throughput is measured in bits per second (bps). The higher the throughput, the better the network and able to send data without packet drop. Fig. 15 explains that the address broker which is 54.73.92.158 are communicating with Raspberry Pi with IP address 192.168.0.144.

This experiment is conducted within three days. There are approximately 1400 messages sent every hour and it approximately generates 42,000 messages per day. The python code will run every second to collect sensor data. The result for three days analysis is shown in Table I. The result includes the date and time, duration, throughput (Raspberry Pi and Broker), network consumption (Raspberry Pi and Broker), and message size.

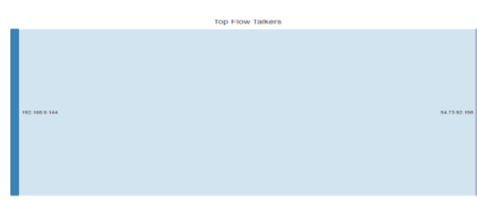

Fig. 15. Ntopng Flow Talker.

TABLE I. THROUGHPUT AND NETWORK USAGE

Date/ Time	Duration	RP T/P (kbit/s)	Broker T/P (kbit/s)	NC from RP (MB)	NC from Broker (MB)	Message Size (bytes)
24/7/2021 00:00:00	0	-	-	5.00	0.05793	296
12:30:00	30min	8.81	1.16	5.29	0.45426	297
01:00:00	1hr	10.49	3.17	9.64	0.98479	297
08:30:00	8.5hr	9.2	2.11	14.98	4.86	296
12:00:00	12hr	9.06	1.16	18.13	6.94	297
25/7/2021 00:00:00	24hr	7.61	1.74	30.77	14.21	296
12:00:00	36hr	5.63	2.11	43.75	21.55	297
26/7/2021 00:00:00	48hr	5.98	1.16	54.49	28.9	297
12:00:00	60hr	8.18	1.05	65.91	36.18	297
27/7/2021 00:00:00	72hr	9.13	3.17	77.15	43.62	297
Total	3 days	-	-	72.15 (minus 5.00MB)	43.62	-
Average	3 days	8.23	1.76	24.05MB/day	14.54MB/day	296.7

*Legend: T/P: Throughput, RP: Rasberry Pi, NC: Network Consumption.

Based on the table above, the throughput of Raspberry Pi is consistent between 5.63 kbit/s until 10.49 kbit/s with an average of 8.23 kbit/s. For MQTT broker throughput, it shows 1.05 kbit/s until 3.17 kbit/s with an average of 1.76 kbit/s. With the speed mentioned, it is considered average and consistent for sending 297 bytes packets to the broker. When testing on the ipantai system that connects with the broker, there is no delay of data. Therefore, the result supports MQTT as the suitable protocol for a system requiring less bandwidth, constrained devices, and high latency. The design principle is to minimise the network bandwidth and device resource requirements while attempting to ensure reliability and some degree of delivery assurance. However, in this research, there are no studies about other brokers that may outperform the investigated HiveMQ broker.

The network consumption depends on throughput. If there are more throughput in the network, more network consumption will be generated. For network consumption in Raspberry Pi, it consumes 72.15 MB during the three days observation. With that, an average of 24.05 MB bandwidth consumption per day is reasonable for an IoT based system to handle and maintain. If the device consumes 24.05 MB per day, it only consumes 721.5 MB per month. Thus, a user only needs to find an Internet plan with the said minimum requirement of 1GB quota per month. In this case, most providers in Malaysia offer around RM19 (USD4) per month/GB. It is affordable for developers to maintain. Since this project is using the beach as the focus of research for data gathering, the Internet bandwidth and coverage are not always available. However, MQTT serves as a lightweight protocol and keeps bandwidth requirements to an absolute minimum, handles unreliable networks and requires little implementation effort for developers. The message sizes are still consistent between 296 bytes and 297 bytes with 296.7 bytes as the average size within the three days. The message size depends on the reading. If there are more decimal places on the readings, more bytes need to be sent. For example, if the temperature increases from 31.0 to 35.456-degree Celcius, more bytes are being sent from the publisher.

The result shows better performance in terms of throughput and message sizes being transmitted compared to previous research [20][21][22]. The possible reason is different hardware [20] is using Wemos D1 R2 as microcontroller and Mosquitto as a broker, different message size [21] and using different cloud brokers such as Mosquitto and Paho [22]. MQTT performs better than AMQP in bandwidth usage and message throughput.

C. Power Consumption

This project uses the smart plug from Tenda for capturing and monitoring power consumption. The model used is Tenda Smart Wi-Fi Plug with Energy Monitoring (SP-9). Tenda SP-9 has included an energy monitoring function that can measure the power used by day/week/months/year. It can handle input from 100 V until 240 V between 50/60 Hz with 13A maximum load. To use the Smart Wi-Fi plug, a mobile device having Android 4.4 or higher or IOS 9.0 or higher is required. A WIFI network is also preferable. The experiment measured the power consumption of the broker and Raspberry Pi for three days. Table II shows an overview of the result taken and presented in the form of a table. The table shows the date and time, duration, current power (W) and power usage (kWh).

In Table II, it is found that the reading is consistent from 0.12kWh until 0.13kWh per day with an average of 0.126kWh. Next, the current power is used steadily from the range 5.26W until 5.65W with an average power of 5.44W. The power consumption of Raspberry Pi depends on the activity running on the operating system. If there is heavy activity such as streaming, the power consumption is significantly higher than usual. This result shows lower power consumption within the range of 0.12kWh to 0.13kWh per day. If it is multiplied by 30 days (1 month), it will consume approximately 6kW. The average electricity tariff per kWh in Malaysia is approximately RM0.32 (USD0.06). Therefore, it cost a minimum amount of about RM1.14 (USD0.30) per month. However, if the Raspberry Pi is powered up by solar, there should be no monthly cost for electricity which is possible for an IoT-based system. The research is that using Raspberry Pi and Arduino compared to another research using different hardware and sensor such as Arduino Uno and Waspmote [23] resulting in more power consumption while publishing data. Some other improvements in designing the IoT-based system may include security features using a goal-based approach [24], [25], explore suitable machine learning algorithms in water research [26], [27] and improve IoT networks using single-on with MQTT [28].

TABLE II. POWER CONSUMPTION (KWH)

Date/ Time	Duration	Current Power (W)	Power Usage (KWH)
24/7/2021 00:00:00 – 23:59:59	24 hours	5.26	0.12
25/7/2021 00:00:00 – 23:59:59	48 hours	5.41	0.13
26/7/2021 00:00:00 – 23:59:59	72 hours	5.65	0.13
Average	3 days	5.44	0.126

VI. CONCLUSION AND FUTURE WORK

In summary, the research has uncovered several significant discoveries. The objectives are to design and develop an IoT-based system for coastal recreational suitability systems and implement an IoT-based system to suit the requirements for capturing, storing, and reporting coastal environment data. The research presented an IoT based system design using MQTT protocol and conducted several experiments measuring the i) message size ii) throughput and iii) power consumption. The result has shown the specified design and system development benefits from using MQTT as the primary protocol of communication between IoT devices. The message size is captured in small packets, which means less data consumption and power required than certain protocols, such as HTTP. The smaller message size makes it ideal for situations where bandwidth is limited, which is an important aspect of IoT devices. The next finding obtained from this research is better performance was presented using HiveMQ broker as part of the configuration compared to previous research. The throughput captured by HiveMQ cloud brokers is faster to send and receive data efficiently. This has also shown that MQTT is lightweight, quick, energy-efficient for a system, which is crucial for the implementation of IoT. Therefore, these findings summarise that the HiveMQ cloud broker has several advantages and is suitable for coastal recreational configuration. As this setup may involve many locations, a cloud broker is suitable and possible future work may need to centralise the connections between many places.

Finally, the findings hope to promote MQTT as the main communication specifically in the industry 4.0 (IR4.0) era. IR 4.0 could enable technologies and a new dimension in environmental monitoring systems to preserve and provide a safer environment for people to undertake coastal recreational activities. In the future, these systems can provide real-time data, decentralise analytics and support decision making.

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Threat Analysis using N-median Outlier Detection Method with Deviation Score

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***Abstract*—Any organization can only operate optimally if all employees fulfil their roles and responsibilities. For the majority of tasks and activities, each employee must collaborate with other employees. Every employee must log their activities related with their roles, responsibilities, and access permissions. Some users may deviate from their work or abuse their access rights in order to gain a benefit, such as money, or to harm an organization's reputation. Insider threats are caused by these types of users/employees, and those users are known as insiders. Detecting insiders after they have caused damage is more difficult than preventing them from posing a threat. We proposed a method for determining the amount of deviation a user has from other users in the same role group in terms of log activities. This deviation score can be used by role managers to double-check before sharing sensitive information or granting access rights to the entire role group. We first identified the abnormal users in each individual role, and then used distance measures to calculate their deviation score. In a large data space, we considered the problem of identifying abnormal users as outlier detection. The user log activities were first converted using statistics, and the data was then normalized using Min-Max scalar standardization, using PCA to transform the normalized data to a two-dimensional plane to reduce dimensionality. The results of N-Median Outlier Detection (NMOD) are then compared to those of Neighbour-based and Cluster-based outlier detection algorithms.**

***Keywords*—Organizational roles; insider threats; outlier detection; deviation score**

I. Introduction

In a distributed environment, all resources such as infrastructure and data are to be distributed among the employees of an organization to obtain better performance and economic growth of the business. But security becomes a major concern in this distributed environment to avoid unexpected loss of reputation or money of their business. In general, security breaches might occur either from externals who have no rights to access any sort of the organization’s resources or from the internals who have legitimate rights to access the infrastructure within the organization [1]. The purpose of insiders is may be to gain money or sensitive data to disrupt the operation or functionalities of an organization. Comparatively, internal threats are harder than external threats to detect. As per the Insider Threat Report by Cyber security Insiders in 2019 [2], 68% of organizations are getting experience with the frequent insider threats. Insider threats can happen by the people purposely or accidentally. Accidental breaches may happen due to careless users or naïve users. 30% of organizations are using some analytical tools to determine insider threat details like user activity management and summary reports in order to reduce the loss caused by these insider threats. Organizations still need to respond quickly in response to the attacks and should be able to identify or predict future threat possibilities. Finding insiders in an organization is a very challenging task to the organizations.

Various Machine Learning (ML) approaches are evolving for carrying out complex and challenging problems that would help to identify and predict malicious intents [4]. In general, a user will be treated as an insider if he/she shows a different behaviour from their previous behaviour and from their peer’s behaviour. The abnormal behaviour of an insider within his allotted role can be defined as the deviation score of a user. Behaviour of a user is nothing but his/her activities or computer system usage in the organization [3]. Researchers are applying either classification or clustering algorithms based on the data that they have gathered regarding insiders. If the dataset includes details of the user's activities in some insider threat incidents, then the researchers can use classification algorithms to build a model with that data. This model will be used in future to classify whether the new user activities can lead to internal threat or not. If the data is about user roles and their activities within the organization, then ML clustering algorithms can be used to cluster the users.

To work on or to analyse the historical data about insider’s activities, The Computer Emergency Response Team (CERT) Division, in partnership with Exact Data, LLC, and under sponsorship from Defense Advanced Research Projects Agency (DARPA) I2O [5], generated a collection of synthetic insider threat test datasets which will be available publicly. The CERT r6.1 dataset simulates an organization with 4000 users’ activities like login/logoff, thumb drive connectivity, file access and their roles over the period of 12 months. The purpose of this paper is to apply existing outlier detection techniques to analyse user activities which are assumed to be generated from different sources and proposed a new N-Median Outlier Detection (NMOD) model to find role wise outliers. Here, a role is nothing but a job role within the organization. This proposed model can able to do the following:

- Aggregate all log files generated from different monitoring tools based on the user activities in an organization.

- Finds the outliers based on the user behavioural patterns when compare with the other users of the same role.
- Generate deviation score of each user based on their activities in a specific role.

The rest of this paper is organized as follows. Section II describes Literature Review; Section III describes the Model for finding the deviation score of a user; Section IV Analyses the Results; and Section V ends with the Conclusion.

II. Literature Review

Insider is an employee in the organization with authorized access rights to access the system resources and knows the vulnerabilities of an organization's infrastructure. The insider is malicious if he/she misuses their access rights to gain benefit out of it. Research on detecting malicious insiders helps the Organizations to take preventive measures.

In the recent years, researchers [4][6][7][8][9][10][11][12] have come up with new supervised and unsupervised Machine Learning (ML) analytical techniques to detect abnormal behaviour of those insiders based on their daily log activities or based on their digital footprints. Researchers of [4] use unsupervised learning techniques such as Isolation Forest and One- class SVM to identify abnormalities in large datasets. They use a trust score which is generated from the previous cycle. Furthermore, they considered the psychometric score of users in their model and checked its effectiveness in identifying insiders. Researchers of [6] mentioned that supervised learning approaches are useful if they have large and balanced data. Otherwise, unsupervised learning approaches are best to predict insiders. They used an unsupervised learning approach called Graph Based Anomaly Detection (GBAD) which is used to detect anomalies in streams. Weekly data is considered as Streams.

William T. Young, et al. [7], uses domain knowledge to develop indicators, anomalies, and scenarios as starting points for analyzing and detecting susceptible insiders. They defined indicators as if any user activity causes any specific attack, then that activity will be considered as an indicator. They defined anomalies as unusual patterns of user behaviour and different log activities are considered as scenarios. They applied unsupervised anomaly detection (AD) algorithms to detect insiders based on the features derived from the previous indicators.

Owen Lo, et al. in [8] uses distance measurement to find the changes in user behaviour and then anomalous insiders. The three distance vector methods that they have used are Damerau– Levenshtein Distance, Cosine Distance, and Jaccard Distance. Duc C. Le, et al. in [9] uses both supervised and unsupervised algorithms on publicly available CERT datasets to detect malicious insiders. They used Self Organizing Maps (SOM) on the datasets and compared it to Hidden Markov Models (HMM) and C4.5 Decision Trees (DT). Duc C. Le, et al. in [10] [11] uses supervised ML techniques such as LR, RF & ANN on publicly available CERT dataset to detect new insider threat cases and considers the data as multiple levels of data granularity to detect malicious insiders and malicious activities. In [12], the researchers transform the security logs to text using Word2vec method to identify the behavioural probabilities. All these are detecting the abnormal behaviour of a user in their log activities not considering their job roles at their working place.

Few researchers [13] [14] [15] have considered the role group of a user to find the deviation score of that user. A. Legg, et al. [13] defined tree-structured profiles for individual user activity and combined role activity. These tree-structured profiles are used to assess how the user's current activities differ from his previous activities and with their peers. The variance of user behaviour from the previous behaviour is treated as deviation score of that user. Researchers of [14] did a sequential analysis using activity tree structure of user behavioural activities. It identifies whether the new activity belongs to the normal behaviour sequence in tree or malicious behaviour sequence of tree. The author in [15] uses a neural network model to do role-based classification of users by learning their behavioural patterns.

None of the above works are generating deviation score of a user and their level of threat severity. Clustering is the unsupervised techniques which can usually groups the entire data into clusters. Deviation score can be found in clustering technique as it clusters the data points based on the distance. But they cluster even an abnormal user to any one of the clusters whereas outlier detection techniques separate the abnormal users from the group of users [23][24][26][27]. But they are using a single threshold value for the entire dataset to find the outliers. That may lead to inaccurate results.

The objectives of the proposed work are:

- Partition the entire dataset into groups by user's job role in the organization.
- Find the threshold value for each group using N-Median distance plot.
- Labeling the outliers in every role group.
- Generating deviation scores of users to predict the possibility of insider threat in an organization.

III. Model to Find the Deviation Score of a User

From the literature review we observed that, most of the researchers have done their insider threat analysis using synthetic data which simulates the real data of the user activities in an organization. Due to the reputation and security concerns, organizations might not reveal their insider threat incidents and their user activities to the outside world. We did analysis of user activities on CERT insider threat dataset r6. 1, which includes 4000 user's activity log files, to produce an activity score of a user and his deviation score from other users within his allotted role group. The details of the datasets are mentioned in Table I.

We used Exploratory Data Analysis on the datasets to understand the correlation and significance of attributes of each dataset. We transformed the features from object type to numeric values before applying suitable algorithms.

TABLE I. DESCRIPTION ABOUT DATASETS

S. No	File	Features	Description
1	Logon	#id, #date, #user, #pc, #activity	gives the information about the user's logon/logoff activity
2	Device	#id, #date, #user, #pc, #filetree, #activity	Each record gives the information about the user's thumb drive connection to the system.
3	LDAP	#Userid, #role	Each record gives the information about the users and their roles in the organization

The system architecture in Fig. 1 shows the processing steps to find the deviation score of users whose behaviour is abnormal comparatively with the other users of the same group. The three datasets login, device & user-role are processed independently using data pre-processing and feature generation techniques to make numerical data ready for applying outlier detection techniques.

A. *Data Pre-processing*

Data Pre-processing is the initial step that every data analyst should perform before applying meaningful data analysis on the data. The main reason for doing data pre-processing is to understand and extract significant features of data [16].

B. *Feature Transformation*

CERT r6.1 dataset contain the raw data which will not give meaningful insight of the data. In a dataset, each represents the details of user activity in the organization like logon/logoff, device connect/disconnect, file open/close and email to within the group/outside the group. Features of those datasets are mapped to labels to count the activities or to apply the statistical analysis on the data. Each data set transformed and extracted features are mentioned in Table II.

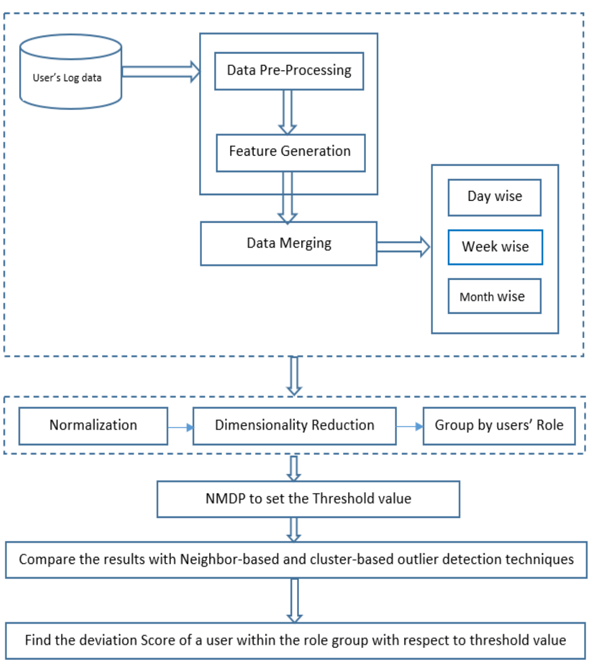


Fig. 1. System Architecture to find the Deviation Score of a user within the Role.

TABLE II. FEATURE TRANSFORMATION

S. No	Name of the File	Transformed Features
1	Logon	#user, #day_only, #pc, #logon_time, #logoff_time, #time_duration
2	Device	#user, #day_only, #pc, #noof_activities, #filelength, #lastactivity_time
3	Role	#user, #pc, #role,

Feature transformation will not change the nature of data or relation between features of data; however, it will influence a lot towards the analytics. It is used to perform data analysis and then to find significant information from the data. We apply aggregate functions on the features by grouping the user activities on a daily basis or weekly basis or monthly basis. The features in the aggregated dataset are of two types.

1) Features that contain count of a particular value like number of PCs, number of late hours, number of logins and logouts, number of devices connected.

2) Features that contain statistical values like variance of user activities per a day, week, month and year.

To find the abnormal behaviour of a user in a week, the mean value of a total number of activities in a week will not reveal accurate behaviour of a user because if a user performs more activities in one day and zero activities in remaining days will give as normal behaviour. But he did malicious activity on the weekend. So, the variation or standard deviation of user activities will produce accurate results.

C. *Data Visualization*

Data visualization reveals a lot of insights in a dataset. We can understand CERT r6.1 datasets and relationships among the features in each dataset. We can visualize the log activities of users on a daily or weekly or monthly basis.

The bar plot is used to visualize the total number of users connected the thumb drives in a week, tells that, a smaller number of users who works on weekends were used thumb drives as shown in Fig. 2(a), the highest number of times device connectivity on a day is shown in Fig. 2(b), the distribution of activities on day10 and day4 is shown in Fig. 2(c) and Fig. 2(d).

We can also observe the variance of a user's behaviour in a week and how their activities are correlated with their variance in login time, numbers of PCs they used and the number of files in the file tree. Fig. 3 shows sample user behaviour in a week.

We can observe that the user has a different behavioural pattern, that is, few days he connected the external device a high number of times and few days he connected a smaller number of times. If we take average external drive connectivity, it may bias the truth. So, we need to transform the raw data into some standard form. Next section we discuss the standardization of data.

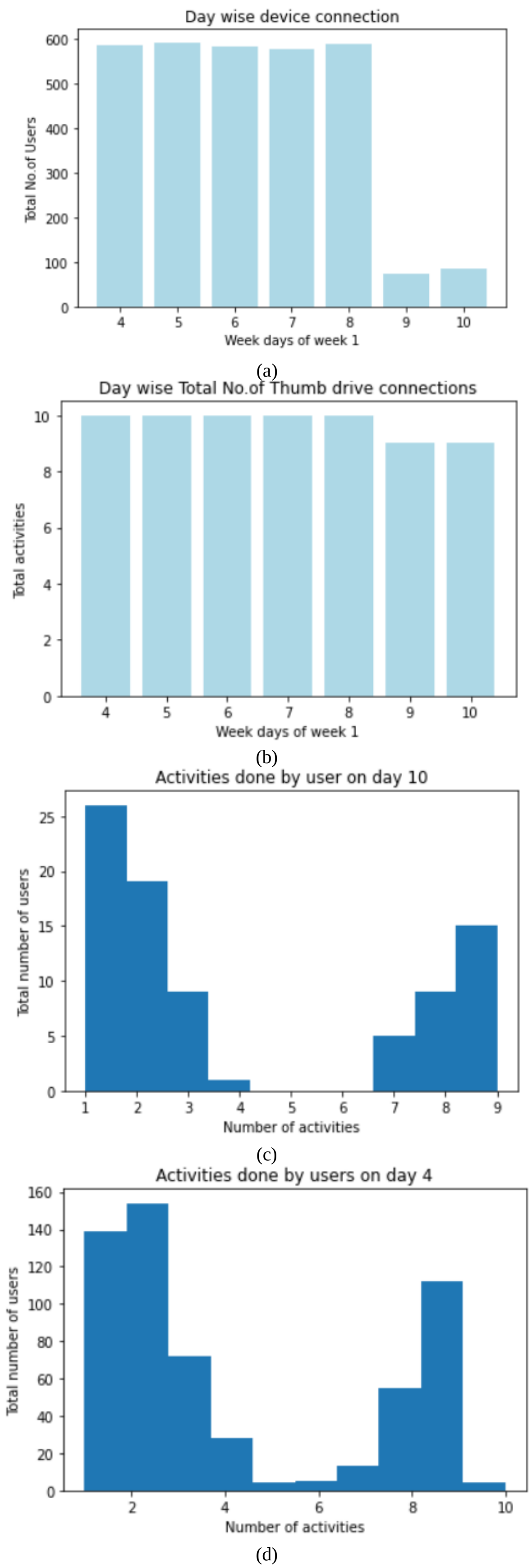


Fig. 2. Day Wise Activities of users.

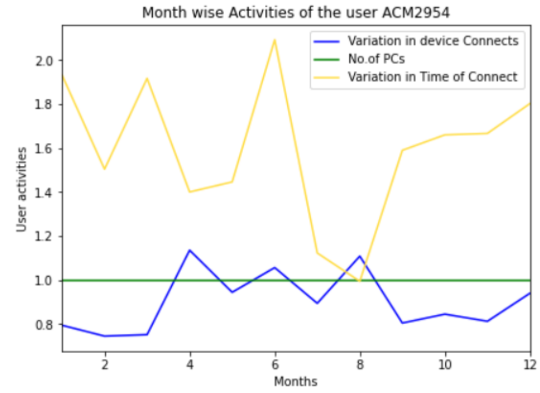


Fig. 3. Month Wise Activities of a user ACM2954.

D. Data Merging

To apply algorithms on the collected data, the data from different sources should be aggregated and transform their features as numerical vectors. We combined day-by-day sessions, days into weeks, and weeks into monthly log activities.

E. Data Normalization

The main objective of this paper is to produce the deviation score of a user from other users in an organization specific role. We are using clustering algorithms to group the users based on their behaviour in the log activities. All clustering techniques form clusters based on the distance computation and they are highly influenced by outliers. As shown in Fig. 2(c) and Fig. 2(d), CERT r6.1 dataset attribute value is not in Gaussian Distribution manner. Large-scaled features will dominate other features [16]. Therefore, for better results, we applied the Min-Max Normalization method before applying the clustering techniques.

Min-max normalization transforms every value in the feature column between the range [0 ,1]. The values will be transformed using the following formula

$$x_i' = \frac{x_i - (F_i)}{(F_j) - (F_i)}$$

Where,

x_i' is transformed feature in the dataset,

x_i is value in the feature column F_i

(F_i) is minimum value in the feature column F_i

(F_j) is the maximum value in the feature column

The minimum value in the column will be transformed as 0 and the maximum value will be transformed as 1. All datasets of CERT r6.1 will be normalized according to the formula to avoid bias.

F. Dimensionality Reduction

As the CERT r6.1 dataset are unlabeled data, we find the deviation score of a user in his allotted role by grouping the users based on user's activity using clustering techniques. AK Jain et al. in [17] given that, feature selection & feature extraction are key steps to obtain the appropriate clusters. All clustering algorithms check the similarities between data points using distance measuring techniques to form groups or clusters. The prominent distance measuring technique is Euclidean distance.

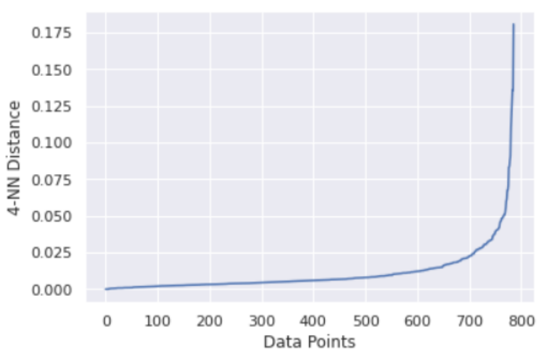
Let $U_i(d_{i1}, d_{i2})$ & $U_j(d_{j1}, d_{j2})$ are two user records, the Euclidean distance between these two user points is

$$dist = \sqrt{(d_{i1} - d_{j1})^2 + (d_{i2} - d_{j2})^2}$$

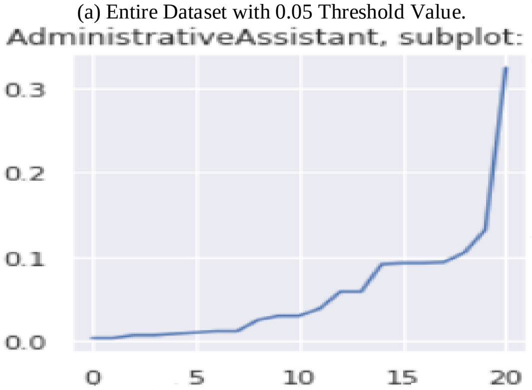
Clustering on a small number of dimensions would give better results than the large scaled dimensionality sample. According to [18] [19], dimensionality reduction reduces the computational load of clustering and also removes the redundant data. Our final dataset consists of nearly 15 features after merging the datasets and which leads to high dimensional problems. We used a popular linear technique called Principal Component Analysis (PCA) for dimensionality reduction without significant loss of information.

G. *Group by users' Role*

To identify whether the user is behaving normally or not, we need to have some threshold value for comparisons. If we set the threshold value for the entire dataset, global threshold, it will check every point with that threshold value and assigns few data points as outliers even if they are normal within their local groups. We partitioned the dataset into groups based on the user roles in the organization and assigns threshold value for each group individually based on their role behaviour. Fig. 4 shows the k-distance plot to estimate the optimal threshold value for finding the abnormality of the user behaviours.



(a) Entire Dataset with 0.05 Threshold Value.



(b) Administrative Assistant Group with 0.13 Threshold Value.

Fig. 4. K-Distance Plot to get Optimal Threshold Value.

H. *Comparing Unsupervised Outlier Detection Techniques with NMOD*

Unsupervised ML techniques are used to analyze the unlabeled data in the dataset. Our purpose of analyzing the unlabeled data is to identify the abnormal behaviour of users and their deviation score with respect to their role group. This problem is considering as the detection of outliers [20][21] in the dataset. Outlier detection finds the different patterns exist in the data and a data point is to be considered as an outlier if it shows the different pattern other than the defined one [22]. The outlier detection approaches are categorized as Statistical, distance-based, density-based and cluster-based. The outlier detection techniques were applied on individual role groups instead of applying on the entire dataset because the access privileges of a user are generated based on his/her role group in an organization.

Statistical Outlier detection techniques are good when the data is univariate and have pre-assumed distribution [27]. CERT r6.1 data sets are merged to find the behavioural patterns of users which is multi feature space. So, statistical outlier detection techniques alone are not applying in the proposed method on the dataset.

1) Neighborhood-based outlier detection: Distance-based Outlier detection identifies a data point as an outlier based on its distance from its k nearest neighbours. Euclidean distance is the distance function used in various neighbour-based outlier detection methods. According to [28], a data point is an outlier if it has less than k neighbours within the predefined distance R. Researchers in [25] defines an object is an outlier if the ratio of k-nearest neighbour distance of an object and the average distance among k-nearest neighbours is greater than 1. The author in [29] says that a point is an outlier if it has highest k^{th}-nearest neighbour distance when compare with all other data points. The author in [30] defines a point as an outlier if it has highest average distance to its k nearest neighbours.

The author in [31] proposed a distance-based outlier detection method to find the top n outliers in the large high dimensional dataset by considering the weights of the data points. Weight of a data point is the sum of the distances from its k-nearest neighbours. Researchers in [32] detects outlier detection solving set for the dataset which is also a distance-based outlier detection. The author in [33] identified outliers by finding the frequency of k-occurrences of a point in the k-NN list of all other data points. Like distance-based outlier detection, Density-based outlier detection methods are also neighbourhood-based detection methods. It finds the outliers based on the density estimation of each data point with respect to their neighbourhood's density distribution [34][35].

2) Cluster-based Outlier detection: Clustering techniques are unsupervised techniques used to group the data points into clusters based on the likenesses between the data points in terms of distance or density of data points. Cluster-based Outlier detection techniques treat a data point as an outlier if it does not belong to any of the cluster. Density Based Spatial Clustering of Applications with Noise (DBSCAN) is the unsupervised clustering algorithm [23] used to form the clusters based on the density-reachability and density-connectivity between the points. Minimum number of points/neighbours (MinPts) and the radius (Eps) are the main parameters to decide the density level, core points and border points. Objects with more than MinPts neighbours within this radius Eps considered to be a core point [24].

Our purpose of using this DBSCAN algorithm is to find the outlier points out of D points in the CERT r6.1 database. We identified 0.13 as the optimal Eps value for Administrative Assistant role group based on K-distance elbow plot as shown in the Fig. 4. It forms clusters and considers the data point that does not belong to these clusters as a noise point. It is not giving the percentage of deviation of a user from his normal behaviour with respect to their role group.

3) N-Median Outlier Detection (NMOD): As per the Hawakin's definition [26], a data point is an outlier if it deviates from the other data point. In our context, we considered any specific user is an outlier in the group if he/she is largely deviating from the other users of the same group. We are using a group wise threshold value to find whether the user is deviating from other the other users of the same role group.

The following are the steps to find the threshold distance value and outliers in the Role group G_i:

- Calculate the (*n* x *n)* Euclidian distance matrix for all data points of the dataset. Where n is the number of data points in a role group G_i.
- Find the median distance m_{P_i} for every point P_i in the matrix. Where each row is distances between a point P_i to each of the other points $\{P_1, P_2, P_3, \ldots\ldots P_n\}$ in a role group G_i.
- Plot a graph with those median values. The first raising edge's corresponding y value consider as the threshold distance TD_{G_i} value for the given role.
- Label a data point as an outlier if its median distance exceeds the threshold distance value.

4) Deviation score of a user in a Role Group: Deviation score is a value between 0 to 1 scale to identify the amount of deviation in the specified role group. If a user's deviation score is greater than 0, we considered them as insiders and role manager can estimate the causes of those insiders. This score helps the role manager to predict the insider threat possibility.

The following are the steps to calculate deviation score:

- Compare every point's median distance value *m* with the threshold value TD_{G_i}.
- Deviation score $DV_{P_i} = \begin{cases} m_{P_i} - TD_{G_i} & if\ m_{P_i} > TD_{G_i} \\ 0 & otherwise \end{cases}$

The complete procedure to find the deviation score of a user in the role group is listed as algorithmic steps in Algorithm1.

Algorithm 1. The pseudo code of outlier detection

```
Input:
  D: Dataset (Device& Log datasets)
  Gi: Role Group
Output:
  Label each user with deviation score
Algorithm
  1. Merge datasets into D
  2. for i in range (1,13): // Month wise
  3.    Data standardization using MinMaxScaler
  4.    Dimensionality reduction using PCA
  5.    Partitioned the Data in to Role groups
  6.    Call NMOD by passing role group Gi
  7.   if (label = = -1)
  8.        Df← Extract the User details
  9.   end if
  10.  Find the deviation score DV_Pi of each user whose label is -1
  11.    end for
  12.    print outliers and their score
```

IV. Analysis of Result

We combined day-by-day sessions, days into weeks, and weeks into monthly log activities. Finally, we iteratively applied the kth-distance, DBSCAN, and NMOD techniques to 12 months of data to find the cluster groups and list of outliers. The proposed N-median outlier detection method outperforms the kth-distance and DBSCAN outlier detection methods. Eps and MinPts are hyper parameters in DBSCAN for clustering users, and k value is user specific for the kth-distance method to find outliers. The k-distance plot is used by both DBSCAN and kth-distance methods to determine their Eps and threshold value, as shown in Fig. 3. The proposed NMOD does not depend on k value and it gives the deviation score for each user in the scale of 0 to 1. Our main objective is to find the deviation score of users to predict the possibility of insider threat in the organization. Table III shows the list of outliers detected by Kth-distance, DBSCAN and NMOD in the role group Chief Engineer.

The listed users are identified as outliers in Chief Engineer group when Eps and Threshold value in both DBSCAN and Kth-distance is 0.12 and k/Minpts value is 3. In N-Median the threshold value is 0.35 from the N-Median distance plot shown in Fig. 5. If we change the Eps and Minpts values in DBSCAN, it will form the two clusters and noise points in the same role group. So, Eps and Minpts are hyper parameters in DBSCAN where as in NMOD it will not take any assumed values and produce the same results.

TABLE III. LIST OF OUTLIERS IN CHIEF ENGINEER ROLE GROUP

Userid	Role	DBSCAN	K-Distance	N-Median
KMP2999	ChiefEngineer	-1	-1	-1
PCJ2393	ChiefEngineer	-1	-1	-1
SCR0171	ChiefEngineer	-1	-1	-1
WCH0096	ChiefEngineer	-1	-1	-1

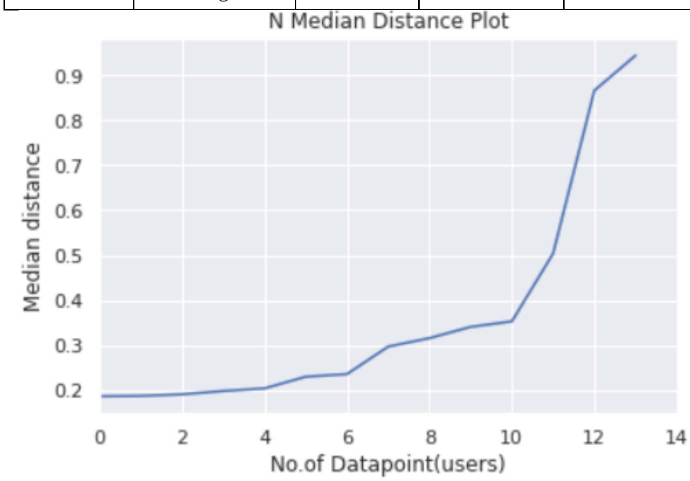


Fig. 5. N-Median Distance Plot.

If we change the k value in kth-distance method, it will generate different list of outliers as shown in Table IV whereas NMOD always gives the same result and there is no ambiguity in choosing the threshold value.

The deviation score of the outliers listed out in NMOD method is shown in the Table V. NMOD also label the users in the role as High (H), Medium (M), Low (L) users for the purpose of role manager to predict the insider threat possibility.

The role manager can use these values to take decision for distributing sensitive data with them in an organization or they can remove from the role group.

TABLE IV. LIST OF OUTLIERS IN CHIEF ENGINEER ROLE GROUP WHEN K=4

Userid	Role	DBSCAN	K-Distance	N-Median
DSL1727	ChiefEngineer	0	-1	0
GJF2381	ChiefEngineer	0	-1	0
KMP2999	ChiefEngineer	-1	-1	-1
PCJ2393	ChiefEngineer	-1	-1	-1
SCR0171	ChiefEngineer	-1	-1	-1
WCH0096	ChiefEngineer	-1	-1	-1
WJV3002	ChiefEngineer	0	-1	0

TABLE V. LIST OF OUTLIERS WITH THEIR DEVIATION SCORE & LEVEL

Index	Userid	Role	DevScore	Level
432	KMP2999	ChiefEngineer	0.154	M
585	PCJ2393	ChiefEngineer	0.594	H
668	SCR0171	ChiefEngineer	0.003	L
746	WCH0096	ChiefEngineer	0.516	H

V. CONCLUSION AND FUTURE WORK

The proposed N-Median outlier detection technique detects the users who exhibit the aberrant behavior when compared to other users of the same job role in an organization. It finds the threshold value using n-median distance plot for each role group. The method will compute the deviation score of each user with respect to their role's threshold value. If an employee deviates from their job role, the role manager must be notified. The deviation score enables the role manager to forecast the possibility of an insider threat in an organization. This approach additionally categorizes the people in the role as High (h), Medium (m), or Low (l) severity based on their deviation score. In this paper, the results of the proposed N-Median outlier detection techniques are compared with the results of kth-distance and DBSCAN outlier detection techniques. N-Median outlier identification does not rely on any of the k values used in kth-distance, nor does it construct numerous groups like DBSCAN does. In future work, we will leverage a user's deviation score in a role to create a framework for safe data delivery to an organization's users via Cloud servers.

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Methods and Architectural Patterns of Storage, Analysis and Distribution of Spatio-temporal Data

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***Abstract*—The work describes the key principles of the process of building digital spatial data infrastructures for effective decision-making in the management of natural systems and for the sustainable development of the regional economy. The following reference points are considered in detail: increasing the accuracy of the deep learning and neural networks algorithmic and software for the process of analyzing spatial data, developing storage systems for large spatio-temporal data by developing new physical and logical storage models, introducing effective geoportal technologies and developing new architectural patterns for presentation and further dissemination of spatio-temporal using modern web technologies. The plan for working out a scientific problem of development of methods and architectural patterns of storage, analysis and distribution of spatio-temporal data determined the structure of the article. The first section concretizes the criteria of efficiency of information processes in the digital spatial data infrastructure (SDI), the second section discusses algorithmic support of the process of analysis of spatial data, the third – integration of spatial data, and finally, the final section – implementation and project-oriented use of geoportal systems.**

Keywords—Spatial data infrastructure; deep learning; neural networks; spatial data; geoportals

I. Introduction

SDI (Spatial Data Infrastructure) is an essential element in addressing the fundamental problem of efficient analysis, systematization and use of large volumes of heterogeneous spatial data, their visualization and dissemination for management decisions on optimizing territorial systems in the context of sustainable development of countries and regions.

The scientific problem of the formation of the theory and methodology for the development of digital technologies in the field of sustainable development, which makes it possible to increase the efficiency of economic activity, prevent and minimize the consequences of natural and natural-man-made environmental emergencies in the context of global climate change, is an urgent challenge of our time.

The development of digital spatial data infrastructures (SDI) should be based on a comprehensive solution to a system of problems aimed at finding effective solutions in the field of integration, processing and analysis, storage, visualization and dissemination of large volumes of spatial and temporal data:

1) Creation and experimental substantiation of new geoinformation methods and algorithms for complex interpretation of remote sensing data, digital maps and auxiliary space-time information using deep machine learning.

2) An experimental study of systemic connections and patterns of functioning and development of natural-social-production systems (NSPS) with the subsequent development of new high-precision algorithms for predicting the development of spatio-temporal processes.

3) Development of a system of methods for integrating knowledge, storing and processing large arrays of spatio-temporal data in digital SDI using cloud technologies, revealing the aspects of effective consolidation, operational analysis and synthesis of relevant data for the purpose of their further use in making management decisions.

4) Creation of effective architectural solutions in the field of building geoportal systems for the integration of knowledge, visualization and dissemination of spatio-temporal data of digital SDI in order to organize a fundamental basis for the synthesis and system analysis of expert information when making management decisions in the field of sustainable development, forecasting the development of natural and man-made processes, including natural phenomena.

The introduction of SDI allows you to approach the solution of the problem of consolidating spatial information for making science-based management decisions. For this geoportal systems required for high-precision automated monitoring of geotechnical systems and for anticipating the consequences of environmental emergencies offer promising avenues for development. SDIs combine software and hardware tools for processing, storing, presenting and delivering geospatial data to end-users to address scientific and applied issues. The visualization, dissemination and use of spatial data infrastructures necessarily address the digital economy.

The plan for working out a scientific problem determined the structure of the article. The first section concretizes the criteria of efficiency of information processes in the digital SDI, the second section discusses algorithmic support of the process of analysis of spatial data, the third – integration of spatial data, and finally, the final section – implementation and project-oriented use of geoportal systems.

II. Criteria of Efficiency of Information Processes in the Digital SDI

SDIs should integrate the following components for analysis, storage and dissemination of geospatial data connected through interfaces.

1) The subsystem of analysis (SA) of large spatial data is used to study and update stored information for effective decision-making within the project.

From the point of view of the potential for attainability of target effects, the following formalized criteria play an important role: increasing of objective metrics (E_{A1}), reduction of type I and II errors (E_{A2}), optimization of expert assessments (E_{A3}). When assessing the resource intensity of performing operations for analyzing spatial data, the following are key: indicators of algorithms optimization ($\Re_{A1}$) and hardware power ($\Re_{A2}$). The complexity of the processes of creating, modifying and using the process analysis subsystem can be determined by the modularity of the model (T_{A1}), optimization of software metrics (T_{A2}), testability indicators (T_{A3}).

The solution to the problem of improving the accuracy and speed of the methodological, algorithmic and software for the process of analyzing spatial data and predicting space-time processes is possible through the development and use of new algorithms for deep machine analysis for the complex interpretation of remote sensing data, digital synthetic landscape maps and auxiliary space-time information in order to implementation of high-precision automated monitoring of the state of ecological-socio-economic systems and forecasting of natural and man-made emergencies.

2) Spatial data storage centers (SDSC) play the role of a system component of the SDI used to provide storage and retrieval of relevant spatial data.

The achievability of target effects is determined by the complexity and completeness (E_{S1}), relevance, reliability and usefulness (E_{S2}), security (E_{S3}) of spatial data. The resource intensity of design-oriented digital SDIs in the implementation of information processes is based on the indexing of records ($\Re_{S1}$), optimization and caching of requests ($\Re_{S2}$), development of search algorithms ($\Re_{S3}$). The complexity of the processes of creating, modifying and using centers for storing spatial data is based on standardization and documentation (T_{S1}), integrity (T_{S2}), database normalization (T_{S3}).

Improvement of storage systems for large spatio-temporal data is possible through the development of new physical and logical storage models, synthesis of relational and NoSQL approaches, the introduction of new algorithms for caching and indexing large information arrays, the creation of methods for storing and processing large amounts of information using cloud technologies.

3) Geoportals are the external component of the system. They play the role of an access point to actual spatial data through search and visualization tools.

The achievability potential of the target effects of geoportals is based on indicators of functional suitability and project orientation (E_{G1}), convenience and reliability of use (E_{G2}), security of user data (E_{G3}); resource intensity when performing operations for obtaining relevant spatial information - based on the indicators of software optimization of the geoportal framework ($\Re_{G1}$), increasing the resources of the dedicated server ($\Re_{G2}$). The complexity (T) of the processes of creating, modifying and using geoportal systems is based on the modularity of the framework (T_{G1}), high modifiability of components (T_{G2}), maintainability of a software project (T_{G3}).

The introduction of effective geoportal technologies and the development of new architectural patterns based on modern web technologies and behavioral optimization makes it possible to organize a fundamental basis for obtaining and system analysis of expert information, forecasting natural processes, providing the foundations for sustainable development of territories.

4) External components and SDI actors are include users and providers of geospatial data and actors interacting with the case law of the system.

From the point of view of the set-theoretic representation, we will give a formalized description of the platform architecture of project-oriented SDIs (Fig. 1). For this, we represent the object of research as a system consisting of a set of interacting elements.

$$S = \langle C, R, Q, X\rangle \tag{1}$$

where S – project-oriented SDI as a system, C – a set of key components into which the project-oriented SDI is decomposed, which, based on the formulated hypothesis, can be represented as $\langle C_{analysis}, C_{storage}, C_{geoportal}\rangle$ where $C_{analysis}$ – spatial data analysis system, $C_{storage}$ – cloud storage centers for spatial data, $C_{geoportal}$ – geoportal system; R – a set of relationships between SDI components, determined by the peculiarities of technical and regulatory interaction; Q – set of properties of key components of SDI and relations $\langle Q_C, Q_R\rangle$, determining the criteria for optimizing spatial data; X – a set of actions with the actors of the system. As the SDI develops, the set-theoretic formula can be refined to reflect the interactions between sets of components.

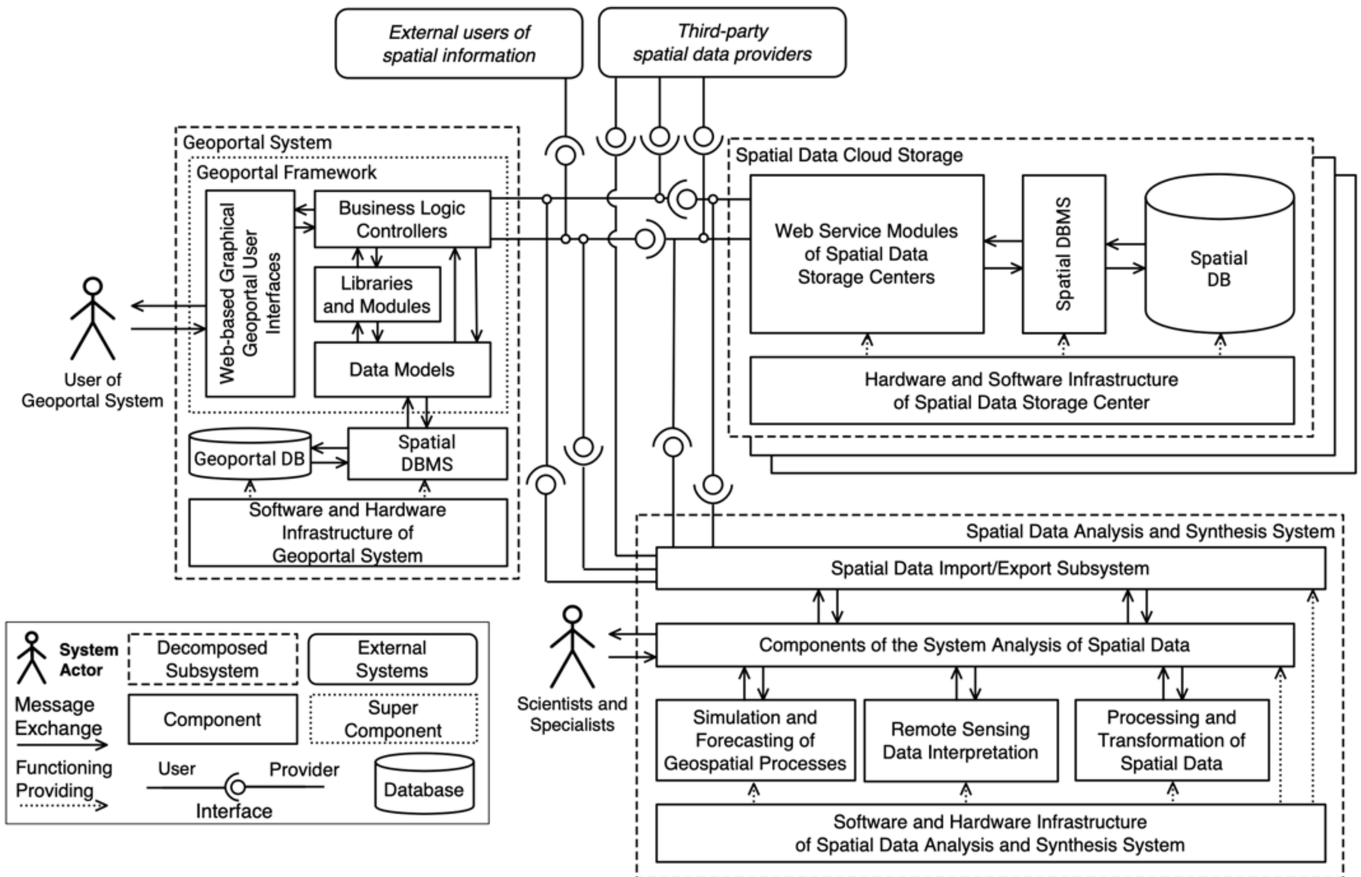

Fig. 1. Structural Component Scheme of Spatial Data Infrastructure.

In order to optimize the use and storage of spatial data, it is necessary to develop criteria for the effectiveness of the projected SDI, defined as follows:

$$P = \langle E, \Re, T \rangle \quad (2)$$

where P – performance indicators of the project-oriented SDI; E – set of target effects of the system, determined by specific aspects of SDI application; $\Re$ – resource intensity of SDI when performing operations of storage, analysis, distribution and visualization of spatial data; T – the complexity (including time) of the processes of building a system, its modification, reorganization and practical use.

Efficiency criteria of a project-oriented SDI for analysis subsystems, data storage and geoportals in order to achieve target effects, reduce resource intensity and time complexity of the system transformation are summarized in Table I.

TABLE I. CRITERIA FOR THE EFFECTIVENESS OF A PROJECT-ORIENTED SDI

Performance indicator	**SDI subsystems**		
	SA	***SDSC***	***Geoportals***
Achievability of target effects (E)	Objective metrics improving (E_{A1}), reduction of type I and II errors (E_{A2}), optimization of expert assessments (E_{A3})	Complexity and completeness (E_{S1}), relevance, reliability and usefulness (E_{S2}), security (E_{S3}) of spatial data	Functional suitability and design orientation (E_{G1}), usability and reliability (E_{G2}), security of user data (E_{G3})
Resource intensity ($\Re$) of SDI	Algorithm optimization ($\Re_{A1}$), increase in hardware power ($\Re_{A2}$)	Indexing records ($\Re_{S1}$), optimization and caching of requests ($\Re_{S2}$), development of search algorithms ($\Re_{S3}$)	Software optimization of the geoportal framework ($\Re_{G1}$), increase in dedicated server resources ($\Re_{G2}$)
Complexity (T) of the processes of creating, modifying and using a component	Modularity of the model (T_{A1}), optimization of software metrics (T_{A2}), testability (T_{A3})	Standardization and documentation (T_{S1}) integrity (T_{S2}), normalization (T_{S3}) of database	Modularity of the framework (T_{G1}), high modifiability of components (T_{G2}), project maintainability (T_{G3})

Let us formulate the supporting points that are critical in the issue of optimizing the use and storage of geospatial data:

1) Improvement the accuracy and speed of methodological, algorithmic and software for the process of analyzing spatial data and predicting space-time processes.

2) Improvement of storage systems for large spatio-temporal data through the development of new physical and logical storage models.

3) Implementation of effective geoportal technologies and development of new architectural patterns of spatio-temporal data using modern web technologies.

Achievement of a comprehensive solution of reference problems will make it possible to obtain a system of effective methods, algorithms and architectural patterns for storage, operational analysis and use of spatial data for the construction of design-oriented SDI.

III. Algorithmic Support of the Process of Analysis of Spatial Data

The development of new geographic information algorithms and methods for analysing spatio-temporal data for analysing land parcels and predicting emergencies is now of great relevance. Evaluation and drawing conclusions based on in-depth analysis of spatial and temporal data are used for various practical tasks, such as environmental monitoring, disaster prediction. Deep machine learning can reduce research costs by allowing accurate interpolation and extrapolation of measurements. In the problem area under analysis, the largest number of publications are devoted to neural networks, for which networks with a multilayer system of non-linear filters are used to extract hierarchical features from the data [1].

The key to improving the accuracy of in-depth analysis of spatial data lies not only in improving the architectures of deep machine learning models, but also in developing efficient data processing [2]. The problem should be addressed from a geosystemic perspective, using the hypothesis of deep relationships of geographical elements [3]. From this standpoint lower level of the hierarchy constituting the territory to be analyzed. On this basis, it can be assumed that the accuracy of the classification of geosystems based on remotely sensed data can be improved if the nomenclature takes into account only the properties of a particular territory, but also the characteristics of the geosystems to which it belongs.

Next, provide a description of the data model that allows us to characterize the territory in terms of the geosystem approach, with a view to subsequently classifying the geosystems using machine learning models that can effectively analyze the data [4].

By classification we mean the operation f executed by the model M, with the experience E. This allows us to correlate a class y specific label with the x_{Local} parameter and in a direct relationship with geosystems and the $x_{Geosystem}$ property vector:

$$y= f(\langle x_{Local},x_{Geosystem}\rangle, M, E) \quad (3)$$

If $x_{Geosystem}$ is empty, we consider the case of classification without involving geodata. Thus, a territory can be assigned to a class based on pixel-based classification or by extracting features from territorial fragments of different sizes (patch-based classification). From a geosystem approach, the properties of a territory are highly dependent on a geosystem. Data from remote sensing of the Earth serve as a source of information. But if strict rules are presented to L_0 level data about $x_{Geosystem}$ object, they must be obtained in a strictly necessary period and of high quality.

The fact that these data have low temporal resolution is the reason for their low price. At the same time, they do not cease to be an informative source of $x_{Geosystem}$ on closed geosystems. Obtaining data from levels L_1, L_2, …, L_N can potentially be automated: it has information about the geographic latitude and longitude of the terrain and it is possible to request a fragment of a space image of the territory with these coordinates of required scale and resolution.

Let us hypothesize that electronic landscape maps and other geographical maps (land cover, land use) are traditionally the ultimate artifact of the process of analysing and classifying remote sensing data, have a substantial amount of information about the territories included in them and form input tensors in the $x_{Geosystem}$ set. The high degree of abstraction indicates that maps have a good potential to enrich information on small classified areas within the geosystems.

To classify information on the geosystem model of the territory, presented in the form of a tuple $\langle x_{Local}, x_{Geosystem}\rangle$, a deep neural network was proposed that accepts data tensors and returning the hypothesis that a given territory belongs to a certain class. This model can be used both separately and in an ensemble with other mono-classifiers.

From the point of view of the black box, the classifier considered above obtains on the inlet images of the territory (L_0) and contains geosystems (L_i) obtained from satellite images as well as synthetic maps (L_S). Their number may vary depending on the territorial model levels, but their growth should be treated with caution, as this will inevitably lead to an increase in the capacity of the model.

The next layer is the batch normalization layer, which allows achieving regularization and model stability. At the end of the feature extraction block is a subdecritization layer that applies the maximum operation to reduce the size of the resulting representations and has external outputs. The next component block of the described model is the feature fusion module. It accepts as input the N-level features extracted from the images of the classified territory. Also, the second and subsequent level merge modules accept the output of the previous merge module as input.

The output layer of the merger module of the last feature is transformed into a vector and fed to the input of the multilayer perceptron. The number and thickness of the interconnected layers are selected on the principle of minimizing these parameters while maintaining sufficient accuracy in the classification. Deep models may examine more signs, but they are very susceptible to problems of retraining [5].

At the same time, an important place is occupied by the problem of adaptation of individual classifiers (monoclassifiers) to a new set of data. It is possible to approach the solution of the indicated problems by combining individual classifiers into ensembles. Research results show that the combination of classifiers into a system improves the stability of the classification algorithm.

The key system components of the ensemble of classifiers can be a set of individual monoclassifiers of various architectural organizations and a metaclassifier – a module that receives data from monoclassifiers for the subsequent adoption of the resulting decision on the belonging of the analyzed spatial territorial object to any class. Let us give a description of the algorithm that determines the variant of ensemble training, according to which the following tasks are sequentially solved: 1) training of individual monoclassifiers, 2) assessment of the accuracy of each individual monoclassifier; 3) training the metaclassifier that analyzes the decisions made by the mono-classifiers of the ensemble, taking into account weighted voting:

$$\begin{cases} H = \operatorname{argmax}_{c\in C}\left(\sum_{i=1}^{N} w(i,c)V(i,c)\right), \\ V(i,c) = 1, \text{if } i-\text{th classifier defines class } c, \\ V(i,c) = 0, \text{if } i-\text{th classifier rejects class } c, \end{cases} \quad (4)$$

where $w(i, c)$ is a weight coefficient characterizing the efficiency of the i-th classifier in detecting territorial objects of class c from the general set of classes C; $V(i, c)$ is a boolean variable describing the fact that the i-th classifier classified the territorial object as class c; N is the total number of ensemble monoclassifiers.

The F_β-score metric can be used as a weighting coefficient of efficiency, which is a value that depends on accuracy and sensitivity.

$$F_{\beta c}(i) = \left(1+\beta^2\right)\frac{precision\cdot recall}{(\beta^2\cdot precision)+recall} = \quad (5)$$

$$= \frac{\left(1+\beta^2\right)TP_c(i)}{\left(1+\beta^2\right)TP_c(i)+\beta^2 FN_c(i)+FP_c(i)}$$

where $TP_c(i)$ is the number of correctly classified territorial objects of class c; $FP_c(i)$ - type I error for territorial objects of class c; $FN_c(i)$ - type II error for territorial objects of class c.

If we take the value $\beta = 1$, then the metric will take the value of the harmonic mean of sensitivity and accuracy (F-score). The methodology for calculating the efficiency ratio can be developed by introducing the concept of an inefficiency threshold. At the same time, the formula for calculating the weight coefficient for the i-th classifier of the ensemble, typical for the definition of territorial objects of class c, will take the following form:

$$w(i,c) = \begin{cases} 0, \text{if } G_c(i) - \varepsilon \le 0, \\ \frac{1}{1-\varepsilon}\left(F_c(i) - \varepsilon\right), \text{if } F_c(i) - \varepsilon > 0 \end{cases} \quad (6)$$

where ε –inefficiency threshold.

The value of the proposed weighting metric will be equal to one in the case of an ideal classifier and zero if the quality of the classification goes beyond the inefficiency threshold ε. In the general case, the presented efficiency metric, which depends on sensitivity and accuracy, determines the model's ability to correctly classify objects of a particular territorial class, avoiding a high number of type I and II errors. If the parameter ε is taken equal to 0.5, the hypotheses of monoclassifiers will be discarded, which gives a result with a simple guessing accuracy.

The process of finding an effective classification of a mono-model can be represented as a decision tree, the main node of which precedes the first stage of the search algorithm, corresponds to the solution of the problem of formulating a study problem. The nodes of the tree define a variant of fixing the state of the model at the i-th stage of the algorithm for finding an effective model.

IV. Integration of Spatial Data

As noted in the previous section, geosystems are systems that are equally geographic, economic, social and technical, including a variety of ecological, social, economic objects, processes, phenomena and their interconnections. It is recommended that basic mapping support be defined a focused SDI as a repository of geographical maps and images for storage in a database and subsequent use to improve the performance of natural and social production systems.

The landscape envelope and the hierarchy of geosystems are the arena for the development of global, regional and local processes of development. In the author's interpretation, a relationship-relationship is any form of correspondence of phenomena, which can be represented in the form of a functional dependence of variable quantities, which has either an unambiguous character or a probabilistic one, and a relationship-interaction is a process of mutual interaction of objects that occurs in real space and time and expressed in a certain course of events that occur with matter and energy in a certain area of space.

Diagnostics and assessment of relationships in the geosystem hierarchy is an important area in the development and practical use of new automated geo-data processing algorithms and supporting space-based temporal formation using machine learning within SDI, continuous updating of cloud storages of large spatial and temporal data for organizations for which the multi-model approach is relevant [6, 7]. The solution to this problem is achieved through the introduction of geoportal systems, which are characterized by a project orientation and are an indisputable basis for the work of state and municipal bodies, which operate strategic sectors of the economy [8, 9].

As a result, it can be argued that in SDI, in order to assess the functioning of natural and social production systems, it is appropriate to distinguish between the following levels of data integration and use:

1) The level of basic spatio-temporal data, including the basic cartographic basis and describing the modern and historical spatio-temporal structure of the geographic envelope, the patterns of interaction of geospheres.

2) The level of spatial models assumes the systematization of data according to the following modules: "natural systems", "social systems", "economic systems", "geoecological systems".

3) The level of decision-making presupposes a project-oriented use of data for organizing the processes of geographical forecasting (and the formation of a complex characteristic of countries and regions (systematizing geodata).

Let us formulate the key principles of spatial data integration from the perspective of the geosystem approach:

1) Modern digital methods for analyzing spatial information form the basis for the study of geosystems representing a hierarchical model of the territory. This technology is promising, as it enhances SDI capabilities.

2) Analysis is enhanced by the use of multiple data warehouses. This provides a broad perspective on the use of spatial data for effective management decisions.

3) No single paradigm the storage of spatio-temporal information in SDI can provide a key to solving all problems, due to the need for different representations for different types of spatio-temporal data. The answer to the problem of integration, storage and processing of large arrays of spatio-temporal information in digital SDIs can be provided by multi-model storages, hybrid databases based on the functionality of different classes of DBMS.

4) The consequence of the use of multi-model storages is the strengthening of the qualitative characteristics of the digital SDI - flexible scaling of the storage as needed, increasing the reliability and fault tolerance.

Spatial data can be stored in data centres or cloud warehouses.

V. Implementation and Project-oriented Use of Geoportal Systems

In the context of the rapid information and economic growth of the regions, the development and use of geoorthographic systems (GIS) plays an important role. Such systems provide access to information on the natural resources, economic and social situation of the regions [10]. Geoportals provide information retrieval and monitoring through integrated research.

Geographic Information Systems, which have inherited the main features of a large number of software systems of a wide range of software information systems, traditionally with high functional interface requirements, with whom they interact with the outside world. These include the Application Programming Interface (API) and the Graphical User Interface (GUI). The first type of interfaces interacts automatically with GIS for data exchange [11]. The GeoJSON, TopoJSON and KML data formats are used to increase the efficiency of this process. In order to make effective use of GIS, it is necessary to develop a reliable and easily modifiable programming interface [12,13].

A review of previously developed geoport solutions highlighted the following key points for an effective interface: 1) focus on flexible development; 2) use of cross-platform web interfaces; 3) focus on future developments; 4) move away from GIS resource management systems; 5) use of necessary libraries; 6) focus on problem solving and achieving objectives.

The main functional requirements for geoorthographic systems are as follows: availability of cartographic data, possibility of combining layers, use of convenient navigational tools, access to the properties of spatial data. Among the many important qualitative requirements are: adaptive GUI for different devices, user-friendly interfaces, portability and extensibility, data security and system reliability.

Let's move on to considering the solutions implemented by the authors of this article, applying the qualitative and functional requirements described above. In order to visualize and disseminate information about the cultural heritage of the landscape of the Republic of Mordovia, a geoportal system "Natural and Cultural Heritage of Mordovia" has been created, accessible at https://tourismportal.net/. The system discloses information about the natural, socio-cultural and infrastructural potential of the region. The portal interface is characterized by its properties of comprehensibility, adaptability, scalability and security.

Several other features of geoportal systems development are implemented in the Lifeshot.info project. The emphasis is on the use of user-friendly cartographic interfaces with news information rather than geospatial information, as is traditionally the case. Thus, more attention is being paid to the cartographic base. The control components receive up-to-date information about news and events occurring in the vicinity of the user. This approach is unique and different from other geoportal and news environments. Scientific novelty is achieved by combining two types of systems.

VI. Conclusion

A set-theoretic approach to the analysis of system properties, elements and their connections of design-oriented SDIs makes it possible to single out the supporting points that are critical in optimizing the storage processes and the subsequent use of spatio-temporal data and identify ways for further research:

1) Improving the accuracy of methodological, algorithmic and software for the process of analyzing spatial data and predicting space-time processes. The solution to this problem is possible through the development and use of new algorithms for deep machine analysis for the complex interpretation of remote sensing data, digital synthetic landscape maps and auxiliary spatio-temporal information in order to carry out high-precision automated monitoring of the state of ecological-socio-economic systems and forecasting natural-man-made emergencies.

2) Improving storage systems for large spatio-temporal data by developing multi-model approach, synthesizing relational and NoSQL paradigms, introducing new algorithms for caching and indexing large information arrays, creating methods for storing and processing large amounts of information using cloud technologies.

3) Implementation of effective geoportal technologies and development of new architectural patterns for visualization and dissemination of spatio-temporal data using modern web technologies and behavioral optimization in order to organize a fundamental basis for obtaining and systematic analysis of expert information when making management decisions.

Achieving a comprehensive solution to reference problems allows you to obtain a system of effective methods, algorithms and architectural patterns for storage, operational analysis and dissemination of spatio-temporal data for the construction of project-oriented SDI.

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Development of Architecture and Software Implementation of Deep Neural Network Models Repository for Spatial Data Analysis

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***Abstract*—The article presents the key aspects of designing and developing a repository of deep neural network models for analyzing and predicting the development of spatial processes based on spatial data. The framework of the system operates on the basis of the MVC pattern, in which the framework is decomposed into modules for working with the system's business logic, its data and graphical interfaces. The characteristics of the developed web interfaces, a module for visual programming for editing of models, an application programming interface for unified interaction with the repository are given. The stated aim of the study determined the structure of the scientific article and the results obtained. The paper describes the functional requirements for the repository as a signific part of software design, presents the developed formalized storage scheme for neural network models, describes the aspects of development of a repository of neural network models and an API of the repository. The developed system allows us to approach the solution of the scientific problem of integrating neural networks with the possibility of their subsequent use to solve design problems of the digital economy.**

***Keywords*—Repository; deep learning; artificial neural network; spatial data; visual programming; software design**

I. Introduction

The development of spatial data infrastructures (SDI), aimed at assessing the state of natural-socio-production systems (NSPS) and forecasting emergency processes and phenomena, plays a system-forming role in solving the problem of strengthening the connectivity of the territories of countries and regions [1]. The data integrated in systems of this class is characterized by a large volume and heterogeneity, as a result of which machine analysis algorithms become the core of systems of this class, which make it possible to solve design problems of various types in the field of analysis of spatial data on natural, social and economic objects that have a distributed geospatial organization [2]. Solving problems of classification, clustering, pattern recognition [3], decision-making and forecasting based on large arrays of spatial data [4] plays an important role in the economies of countries and regions [5]. Artificial neural networks are of great importance among models and algorithms for data analysis [6].

This article is devoted to solving the scientific problem of the formation of architecture and the development of software implementation of the repository of deep neural network models for the analysis of spatial data, integrated into a single system to support the process of making managerial decisions in the field of ensuring conditions for sustainable development of territories.

The solution to the problem of effective use of neural networks meets many unresolved challenges, an important place among which is the problem of integrating deep neural network models into a single system in order to form a convenient toolkit for specialists in the field of data analysis. Currently, the generally accepted practice is the consolidation of data analysis algorithms in repositories - information systems focused on the formation of the ability to search, store, develop and efficiently use the accumulated project-oriented solutions.

The stated aim of the study determined the structure of the scientific article and the results obtained. The paper describes the functional requirements for the repository, presents the developed formalized storage scheme for neural network models, and describes the aspects of development of a repository of neural network models and an API of the repository.

II. Related Works, Materials and Methods

The task of designing a repository of neural networks has its own specifics, due to the fact that the process of training deep models is often characterized by high requirements for computational resources [7, 8]. On the other hand, the very formation of the topology of neural networks, the selection of hyper-parameters of models is a non-trivial task that can be solved in many ways and requires the involvement of expert systems to make decisions [9, 10]. Finally, the generated neural network model repository should be deeply integrated with existing machine learning frameworks (Tensorflow [11], PyTorch [12]) to ensure high practical efficiency of the repository and reduce the gap between data scientists and software developers [13].

Currently, there are a number of examples in the field of developing deep neural network model repositories, among which Wolfram Neural Net Repository [14] and the Amazon Web Services (AWS) marketplace [15] should be highlighted. The presented repositories are characterized by different architectural and structural organization, individual software solutions. For example, Amazon Web Services matches each model with a set of different criteria and filters to find the model. At the same time, we note that when solving the problem of analyzing spatial data, its own specificity is formed, which imposes restrictions and new requirements on the implementation of the repository of neural network models presented in [16].

The development of the repository is based on the ontological model of the repository [17], which defines the principles of systematization of deep models for the analysis of spatial data by classes of problems to be solved, the nature and dimension of the analyzed data, architecture and topology, and efficiency properties (Fig. 1). The deep neural network models repository was created on the basis of the object-oriented analysis and design paradigm using the unified modeling language UML for visualization, specification, design and documentation of software systems [18].

From the point of view of software implementation, the described software system operates on the basis of the MVC pattern [19], which presupposes the decomposition of the project framework into controllers (modules designed to describe software business logic), models (components for manipulating data) and views (sets of templates for forming adaptive web interfaces). To implement the functional of visual editing of the model, the JavaScript programming language was used, the component was tested in the formation of models of neural network architectures.

An important function of the deep neural network model repository is to provide end users with different roles in the system adaptive web interfaces for quickly obtaining systematized information about the optimal deep neural network model to use, which should include a structured description, performance indicators, architectural and topological organization, and so on. the same recommendations for flexible tuning of model hyperparameters, examples of applied use in solving project-oriented problems. To organize the work of the storage of neural network models, a multi-model approach was used, and software interfaces for exchanging data with external systems are implemented on the basis of the GraphQL paradigm [20].

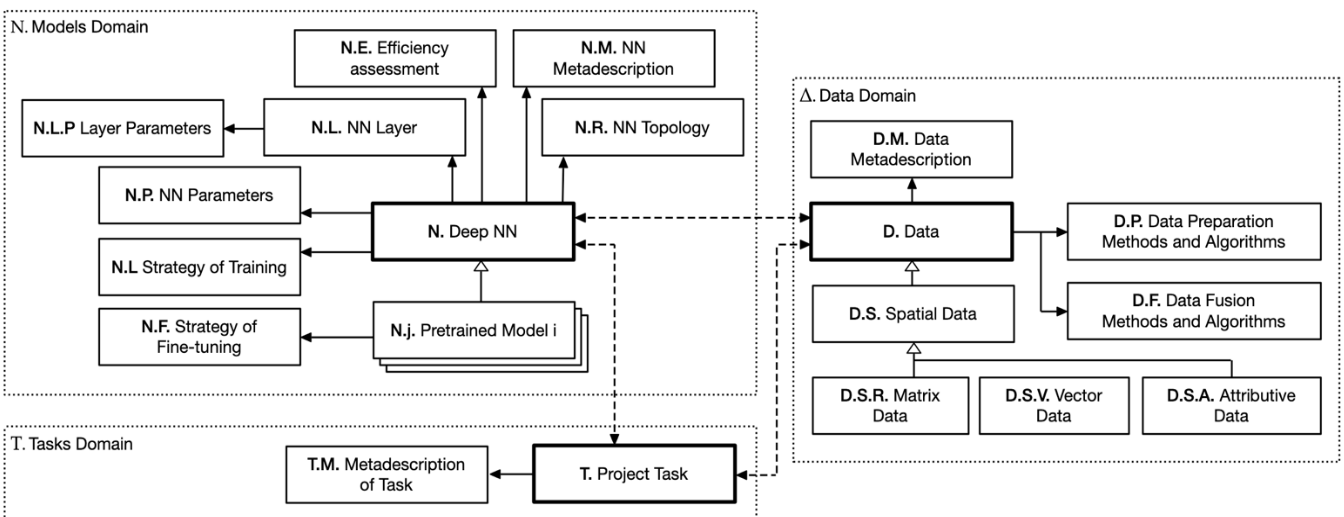

Fig. 1. Ontological Model of the Repository.

III. Research Result

A. Functional Requirements for the Repository

In order to systematize the functional requirements for the repository, we will form a UML use-case diagram (Fig. 2). The initial use case of the repository is described by the precedent "L. Authorization in the repository", the purpose of which is to ensure the differentiation of rights to read, use and edit neural network models. The designated functionality is implemented by providing a form for entering authentication data to an unauthorized user in the system.

After authorization in the system, the user gets access to individual modules of the repository based on the existing rights. From the point of view of software implementation, the described software system operates on the basis of the MVC pattern, which presupposes the decomposition of the project framework into controllers, models and views, which makes it possible to increase the cohesion of individual repository modules and reduce the coupling between them.

The Administration use-case group includes two use cases: "AU, User Management" (managing the distribution of roles, adding, editing, deleting metadata about users) and "AL, Management of logs" (forming the ability to view system logs with the ability to search and filter in order to moderate the operational processes of working with the repository).

The Neural Network Model Management use case group includes the use cases that form the core of the system. The integrating case "M. Model database management" is decomposed into the "MN. Navigation in the catalog of models" (through the filter system), including the "MR. Recommended system for model selection" (allowing to provide relevant search, selection and configuration of deep neural networks, fine-tuning of models for solving specific design problems in the field of spatial data analysis). The model data management CRUD also includes the use case "MA (Model addition)" and expanding its functionality "ME (Model modification)", which allows you to create and edit deep neural networks.

A separate description of the functional component "MV Visual editing of the model" as a constituent block of the described CRUD-subsystem, allows visualizing deep learning neural network models in the form of a graph-diagram, with the possibility of interactive online editing of the topology and model architecture through a thin client (web browser). To implement the functionality of visual editing of the model, the JavaScript programming language was used, the component was tested in the formation of models of neural network architectures presented in the Keras open neural network library (Fig. 3).

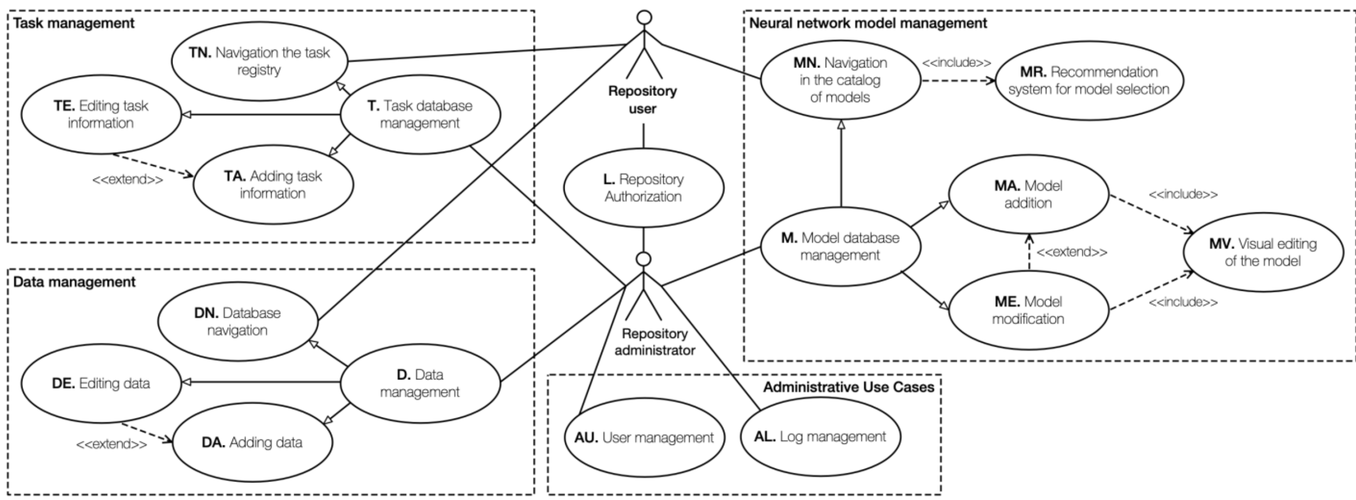

Fig. 2. Deep Neural Network Model Repository use Case Diagram.

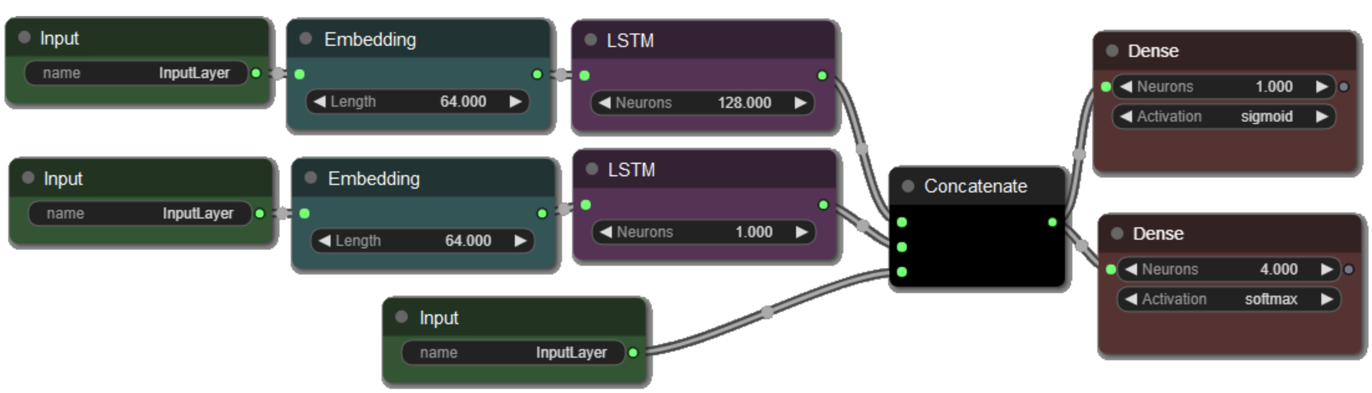

Fig. 3. Visualization of a Neural Network Model in the Form of a Graph Diagram: A Model with Three Inputs and Two Outputs.

According to the previously developed ontological model, the domain of deep neural network models should be associated with the domains of design tasks and analyzed data. Use cases corresponding to the designated subject areas are also implemented in the repository in the form of CRUD subsystems "Administration of the task base" (based on the use cases of "TN, Navigating the task registry", "TA, Adding task information", "TE, Editing task information") and "Data management" (formed by use cases "DN, Database navigation", "DA, Adding data"; "DE, Editing data").

B. Formalized Storage Scheme for Neural Network Models

The development of a formalized storage scheme for models of deep machine analysis of spatial data in the form of a meta-language made it possible to convert them into representations used by modern machine learning frameworks [4].

In order to optimize the integration processes and the practical use of deep neural network models, a formalized scheme for storing models in the form of a meta-language was developed, which makes it possible to convert them into representations used by modern machine learning frameworks (for example, Keras). Let us present the description of the designed meta-language from the point of view of the set-theoretic approach and take the set of repository models $MODELS$ (1) (the power of which is determined by the number of repository models) as a universal set:

$$MODELS = \{MODEL_i | 1 \leqslant i \leqslant N \wedge i \in \mathbb{Z}\} \tag{1}$$

The topology of the model of a specific deep neural network model $\mathrm{MODEL_i}$ can be represented in the form of a graph-scheme $\mathrm{GRAPH_i}$ and a structured meta-description $\mathrm{META_i}$ (2). In turn, the meta-description of the model is generated based on the $\mathrm{DESCRIPTORS_i}$ descriptor array (including the model name, annotated description, performance metrics, etc.) and the $\mathrm{COMPILATION_i}$ assembly parameters. The graph-diagram of the $\mathrm{GRAPH_i}$ model is a directed graph, the set of vertices $\mathrm{LAYERS_i}$ of which determines the set of layers of the deep neural network model, and the set of arcs $\mathrm{LINKS_i}$ determines the structure of the neural network, establishes directional connections between the layers.

$$MODEL_i = \langle META_i, GRAPH_i \rangle = \langle\langle DESCRIPTORS_i, COMPILATION_i \rangle, \langle LAYERS_i, LINKS_i \rangle\rangle \tag{2}$$

A tuple of model assembly parameters $\mathrm{COMPILATION_i}$, includes an object $\mathrm{optimizer_i}$, which describes methods and algorithms for optimizing the neural network model (including stochastic gradient descent (SGD), adaptive model estimation (Adam), root mean square propagation (RMSProp) and others), as well as parameters their functioning. The loss function $\mathrm{loss_i}$ defines the parameters that the model should strive to minimize during training to solve regression and classification problems. Finally, the $\mathrm{metrics_i}$ object defines the function used to evaluate the performance of the model, while the calculated metrics values are not used in the training of the model. Various metrics can be used in the formation of models for solving problems of multiclass and binary classification, regression, segmentation. The description of the tuple of model assembly parameters from the point of view of the set-theoretic approach is as follows (3):

$$COMPILATION = \langle optimizer_i, loss_i, metrics_i \rangle \tag{3}$$

An important component of the graph model of a deep neural network model i is the $\mathrm{LAYER_{ij}}$ layer (4), which, from the point of view of a formalized description of the model, can be represented as a set of objects that determine the type and architecture of the layer $\mathrm{TYPE_{layer_{ij}}}$, a set of interfaces of the $\mathrm{INTERFACES_{ij}}$ layer, $\mathrm{PROPERTIES_{ij}}$ arguments that determine the features the functioning of the layer, descriptors of the $\mathrm{VISUAL_{ij}}$ visualization, which determine the features of the model visualization within the framework of adaptive web interfaces:

$$LAYER_{ij} = \langle TYPE_{layer_{ij}}, INTERFACES_{ij}, PROPERTIES_{ij}, VISUAL_{ij} \rangle \quad (4)$$

The $\mathrm{TYPE_{layer}}$ object defines the architecture of the layer and decisively specifies the data processing and hyperparameter settings when training the model. The base layers of the model (the BASE group) are represented by the following architectures: an input layer (Input), a fully connected layer (Dense), as well as a custom programmable layer (Custom Layer), the architectural organization of which can be specified by the user. Layers for building convolutional models (the CONVOLUTION group) includes convolutional layers that process data of different dimensions (Convolution), layers of separable convolution (Depthwise Separable Convolution), as well as layers of subdescription (Pooling). Recurrent layers are represented by architectures of fully connected recurrent layer (RNN), long short-term memory layer (LSTM), managed recurrent blocks (GRU), long short-term memory convolutional layer (Convolutional LSTM). Finally, the meta-language for describing deep neural network models supports layers of reshaping (Reshape), merging and merging (Fusion), element-wise merging based on mathematical operations (Add, Average, Maximum, Minimum, Multiply, Subtract). Finally, regularization layers) and decimation (Regularization) Thus, many categories of the architectural organization of the layers of the repository can be represented as a tuple (4):

$$TYPE_{layer_{ij}} = \langle BASE, CONVOLUTION, RECURRENT, RESHAPE, FUSION, MERGING, REGULARIZATION \rangle \tag{4}$$

The parameters of the interface $\mathrm{INTERFACES_{ij}}$ of the $\mathrm{LAYER_{ij}}$ layer (inputs $\mathrm{INPUTS_{ij}}$ and outputs $\mathrm{OUTPUTS_{ij}}$) are defined by a tuple of parameters $\langle \mathrm{name}, \mathrm{type} \rangle$, where the name object specifies the interface name, type is the data type and dimension (5).

$$INTERFACES_{ij} = \langle INPUTS_{ij}, OUTPUTS_{ij} \rangle = \langle \{INPUTS_{ij\lambda} | 1 \leqslant \lambda \leqslant \Lambda \wedge \lambda \in \mathbb{Z}\}, \{OUTPUTS_{ij\mu} | 1 \leqslant \mu \leqslant M \wedge \mu \in \mathbb{Z}\} \rangle \tag{5}$$

The set of arguments $PROPERTIES_{ij}$ sets the hyper-parameters that determine the model of the layer $LAYER_{ij}$ (6). This set of named arguments may differ for layers of different architectures and may include, for example, specifying methods and algorithms for initializing layer weights and regularization, activation functions:

$$PROPERTIES_{ij} = \langle initializer,\ activation,\ regularization, \{keywordArguments_k \mid k \in \mathbb{Z}\}\rangle \quad (6)$$

Finally, in order to provide visualization of deep neural network models within the framework of adaptive web interfaces, the meta-language for describing the model involves storing the parameters of the $\mathrm{VISUAL_{ij}}$ group, which are not responsible for the functional and qualitative features of the neural network, but determines the aspects of its visual graphical display (7). The object of the $\mathrm{META_{ij}}$ group is characterized by the title information $\mathrm{title_{ij}}$ and the $\mathrm{scheme_{ij}}$ rendering scheme, which determines the color scheme of the layer within the framework of web interfaces and other styles. The elements of the $\mathrm{POSITION_{ij}}$ tuple define the $\mathrm{top_{ij}}$ and $\mathrm{left_{ij}}$ coordinates of the layer's location on the render canvas, and the $\mathrm{SIZE_{ij}}$ tuple defines its $\mathrm{width_{ij}}$ and $\mathrm{height_{ij}}$ dimensions.

$$VISUAL_{ij} = \langle META_{ij}, POSITION_{ij}, SIZE_{ij}\rangle = \langle\langle title_{ij}, scheme_{ij}\rangle,\ \langle top_{ij}, left_{ij}\rangle,\ \langle width_{ij}, height_{ij}\rangle\rangle \quad (7)$$

To combine the $\mathrm{LAYERS_i}$ layers of the i model, a set of $\mathrm{LINKS_i}$, links is introduced into a single model, in which each object is characterized by a set of parameters defining the source layer ($\mathrm{LAYER_{origin}}$) and its output interface ($\mathrm{OUTPUT_{origin}}$), as well as the destination layer ($\mathrm{LAYER_{target}}$) and its input interface ($\mathrm{INPUT_{target}}$) (8).

$$LINK_{ij} = \langle\langle LAYER_{origin}, OUTPUT_{origin}\rangle,\ \langle LAYER_{target}, INPUT_{target}\rangle\rangle \quad (8)$$

An application programming interface designed on the basis of the REST architectural pattern and GraphQL paradigm provides the possibility of a unified interaction in order to exchange data with a repository for importing and exporting neural network models and obtaining information about them).

C. *Development of a Repository of Neural Network Models and an API of the Repository*

A comparative analysis of documentation, use cases, market needs made it possible to identify several databases suitable for solving the problem of storing neural network models and built on the basis of various paradigms: PostgreSQL (an object-relational DBMS that can be successfully used for structured presentation of data from different knowledge domains of a repository) , Neo4j (graph storage that can be used to store data about the topology of neural network models), InfluxDB (a database for storing time series that allows you to keep temporary training statistics, track progress and save the trained weights during training).

Each individual paradigm for organizing a repository of deep machine learning models does not answer all the questions that arise when solving the problem of systematizing information from data domains, deep neural network models and design problems. A comprehensive answer to this problem can be provided by multi-model database management systems, which are hybrid storages that can be centralized in the data center, or presented on a cloud scale, the operation of which is based on the superposition of the capabilities of different classes of DBMS. The result of the competent use of multi-model data management systems for the repository of deep neural network models should be a purposeful enhancement of the qualitative characteristics of the generated storage of neural networks, including scaling and modularity, fault tolerance and reliability.

To solve the problem of deploying an application programming API in order to exchange data about a specific neural network for use in further computations, it is proposed to use the GraphQL paradigm, which makes it possible to form a group of microservices that are weakly related to each other. This allows greater scalability, more precise customization for user requests and reduces the load on the global nodes of the system.

The application programming interface of the repository of neural network models provides the possibility of unified interaction with the system for data exchange in order to import and export neural network models and obtain information about them). It should describe the ways (that is, a set of functions, classes, constants, or structures) through which a software system can interact with a model store. The API interface, implemented using GraphQL technology, defines the syntax that describes the format for requesting data from the repository server, and also provides an environment for executing such requests. The advantages of using this technology are as follows: GraphQL allows the user to specify exactly what data he needs without reloading the request with unnecessary information; making it easy to combine data from different sources.

When organizing a microservice architecture, it becomes possible to create a system of methods and algorithms for obtaining data of various types, thereby reducing the load on the system as a whole. GraphQL is also capable of providing seamless access between existing services. The convenience of using this technology is that after setting up GraphQL, the entire set of microservices acts as a single whole, and GraphQL regulates the flow of requests. This allows you to get a fully automated system that does not require developers to write additional interfaces when interacting between microservices and system interfaces.

IV. Conclusion

The article describes a project devoted to solving the scientific problem of accumulating and systematizing deep neural network models by designing and developing a repository of learning algorithms for analyzing and predicting the development of spatial processes.

From the point of view of software implementation, the framework of the system operates on the basis of the MVC pattern, which involves the decomposition of the project framework into controllers, models and views. Emphasis is made on the development of adaptive web interfaces that allow using the repository using a computer connected to the Internet.

The visual model editing module allows you to visualize neural network models in the form of a graph diagram, with the possibility of interactive online editing of the topology and model architecture. An API based on the GraphQL paradigm provides a unified interface to communicate with the repository to import, export, and retrieve information about models.

The designed architecture of the repository of deep neural network models and its software implementation allows us to approach the solution of the scientific problem of integrating neural networks, pre-trained models with the possibility of their subsequent use to solve design problems of the digital economy.

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The Development of Green Software Process Model

A Qualitative Design and Pilot Study

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***Abstract*—Software process and development are the fundamental activities in software engineering. Increasing software usage either develops in-house or outsourcing requires improving the software process accordingly to minimise the adverse effects on the environment. The resources and power consumption controlled by hardware affected the software to move the process that causes high emission of power and energy. Thus, most of the existing work on software development is aimed at the efficiency of hardware operation through CPU, memory, and processor. Although sustainability is still initial in software engineering, the green software process can be achieved through sustainable development that concerns the preservation of the environment. However, there is still a lack of study and effort in the software process that emphasises sustainability perspectives and software waste elimination. Therefore, this study proposes the green factors for the software process that consider the sustainability elements and waste reduction during development. The green factors are the benchmark to measure a sustainable and green software process. Besides, this paper also presents the qualitative interview design and pilot study. The pilot study analysis has demonstrated the reliability of the interview protocol. Therefore, the actual interview and data analysis are currently in progress.**

Keywords*—Software process; green factor; waste reduction; qualitative instrument; green software process model

I. Introduction

Software was becoming crucial and became part of our life today. The development of software systems needs to reflect on sustainability and environmental impact [1]. Software is vital to do work and tasks more efficiently. Software causes hardware activity, and it is responsible for the increment of energy consumption in that way. It has become the central aspect of daily life, and most people cannot imagine that future development without software.

Electricity consumption in the ICT sector is expected to increase by 60% from 2007 to 2020. Since ICT contributes to 2% of carbon dioxide emissions from the electronics, household, ICT services, and equipment sector, an estimated 8% is from electricity consumption [1]. Systematic methods for improving the organisation's environmental sustainability provided several guidelines such as the Eco-Management and Audit (EMAS) Scheme, the ISO 14001 standard, and the Environmental Management System (EMS). Meanwhile, large organisations need to publish their organisation's corporate social reports for employee compliance [2].

Generally, sustainability means the beginning to nurture the future generation aligned with the present and compliance with the own needs [3]. Sustainability in the software system is a concept of recycling to protect the environment as excessive waste production can harm the environment's well-being [4]. In addition, sustainability is a resource to support life and the environment that requires the courage of individuals or communities to be maintained for a long time [5]. In engineering, it needs to demonstrate efforts to improve the environment, social and economic. Therefore, sustainable software development is for the system requirements required [6] to ensure the sustainability of nature.

Today, "going green" is an essential part of business practices worldwide related to the environment [7]. Several factors that determine the greenness of the software process have been considered that take into account the sustainability aspect such as resources and products [8][9], people [7][10], organisation [11][12], technical [13][14], and environmental [15][16].To create every phase of the software process sustainable, it must go through the green strategy, guideline, and green metric that ultimately reflect the greenness of the entire stage [4].

Over the past three years, green software engineering has grown and evolved due to concerns over the software, industry, and consumers' development. However, it focuses on the fundamental aspects of energy efficiency and power consumption, affecting the environment [17]. Many studies discuss green software development that focuses on hardware perspective on energy efficiency and power consumption [18]. Green software development as a whole, the software process methodology should be considering investigating their requirement to create sustainable and green manner.

Green software engineering goals are to minimise the negative effect on the environment [1][19] and produce sustainable software products. Previous studies [20-23] emphasise green hardware in energy efficiency, power consumption, waste reduction, and disposal. However, it seems to lack studies on green software even though the impacts are direct to hardware[17], but the software also indirectly impacts. The initiatives of green software are to save resources such as energy, power, and natural resources to preserve the stability of the ecosystem [24]. Nowadays, the software is no longer viewed in terms of productivity but needs to focus on scalability, usability, and quality [25] with recent advances in-demand new technology.

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Therefore, this research is essential to ensure the software development process complies with the green requirement as needed by the community and industry in general. Currently, the green development issues are not being focused on comprehensively, especially from a sustainability perspective.

The article organisation is as follows. In Section 2, we discuss the background study and related works of the green software process. While in Section 3, the research method and activities are presented. It discusses the approach of carrying out this research. In Section 4, we will discuss the qualitative design and pilot analysis, and lastly, we will conclude this paper with a conclusion and future work.

II. Related Work

The software process is a work in progress requiring changes to the user's needs to use the software effectively. In addition, the target of the software process is to improve the job done and used by various companies facing the inevitable difficulties and uncertainties of the process software. Some aspects of software development require the user's attention; the product developed should reach the customer well based on the specified cost and time [26].

Applying green practices as part of the software development process attempts to achieve a green software process. It means to practice for the software is considering the environmental aspects. In addition, the software process involves the development, operation, and maintenance that is carried out in a green approach and producing green software processes. Besides, the green software process can create less waste throughout the development [17, 22].

The transition to the green software process requires careful study as it involves several critical activities in the software development process. The implementation of green initiatives can be done in phases, observing how the software works without cost during the software development process. Research on the transition and development of green software processes is to improve the practices of the process. There are ways to develop green software processes that are to implement green software process practices. Implementing this method supports reducing waste during software development, such as unproductive workers, power savings, and resources.

A. Issues and Challenges in Green Software Process

Information and Communication Technology (ICT), particularly in software development, remains significant and increasingly important even with the emergent of new areas such as big data, cloud computing, Cyber-Physical Systems (CPS), and IoT [25]. Nevertheless, software development still has issues and challenges maintaining relevance and sustainability of the process to ensure the quality of the developed product.

1) Software development process: As described by [27], software development involves a wide range of skills and disciplines, including identifying user needs, values, and features that support the final product. Software development projects have many obstacles and barriers to complete and deliver the project. Several factors come from the organisation environment, team, and user perspective that are not well-prepared according to requirement, budget, and time [28-29]. Most software development projects failed due to higher budgets, overtime, and low customer satisfaction. According to [25], the causes of failures are time, finances, staffing, and management.

Various software projects are often ambiguous, where the goals and objectives are unclear due to the lack of experience from the users. Software project development requires a lot of communication and the time taken to complete it successfully. As developers, they are intelligent users who do not use specialists to translate their needs into software engineering. In addition, developers should engage users in software development to help them understand the needs and delivery of project functions well. Users involvement [26], from the beginning of software development to the end, is vital as this is one of the criteria for the success of a project.

Generally, the software process has five main phases: requirement specification, design, implementation, testing, and maintenance. Some activities in this phase may cause problems and challenges, especially in fulfilling current demands such as reducing paper use, e-waste generation, and controlling carbon footprint and energy efficiency.

Shenoy and Eeratta [22] suggested creating sustainable and green software processes without adversely affecting global economic, environmental, social, and individual well-being. At the same time, there are five primary and fundamental activities associated with the development process and will be discussed in the following subsections:

a) Requirement Specification Phase: The requirement specification is an important activity in software development. It is conducted with the specified team by getting information from the users. The software requirements specification (SRS) is delivered as the outcome of requirement gathering and analysis activity [30]. A good software requirement specification aims to satisfy the needs of its customers. Based on [31], some possible green analysis criteria include viability, requirements, and tests.

Many problems exist in requirement analysis, such as lack of user input, incomplete and frequently changing requirements, and specifications. The literature suggested coming across the software regarding its lifespan and durability [22]. In addition, the collection of requirement specifications is required through electronic methods to save resources such as paper and preserve the environment. Furthermore, as [30, 32] suggested, software should adopt new hardware for energy efficiency and coping with power down during its operation.

b) Design Phase: The functional and technical requirements gathered during the requirement stage create the design document and artefact. During the design phase, the SRS is referred to as the primary reference for product architecture.

This documentation is supportive of the software development process. Therefore, the design team needs to cooperate with the software developer on this document before proceeding to the next phase. All stakeholders must review the Document Design Specification (DDS), and the best approach is selected based on budget, time constraints, risk, robustness, and design method [30]. Reference [31] suggested that performance, reusability, and documentation are among the green analysis criteria in the green process. Design reuse and virtual design are also other factors defined in the green process by [33]. Furthermore, previous researchers [22, 33] argue that the initial design should be moderate to avoid frequent design changes. The design should not be too large and lead towards practices that protect the resources.

c) Implementation Phase: Implementation and coding are the subsequent activities in the software development process. The source code is generated based on a detailed and well-organised design to avoid problems during the development. This phase involves source code written in specific programming languages based on the developer's preference and the project approach.

The implementation phase is an emphasis on programming. There are several things to avoid, which are the use of duplicate code, custom hardware APIs, and resource-intensive APIs. It encouraged the user to utilise the high resources on tap systems that need to process programming complexity. In addition, paired programming, code reuse, and automated code generation support minimising and saving energy consumption [22].

The guidelines in the design and implementation phase can support the sustainability of the environment if the programmer needs to be proficient in writing algorithms by summarising design code and data structure according to the hardware architecture, programming languages, and applications. Programmers must produce practical algorithms by minimising the number of program lines to reduce their execution later. As mentioned by [33-34], extending the program code requires energy efficiency and additional work to execute the code.

d) Testing Phase: The testing phase relates to the product errors detected and re-analysed until they meet the quality requirements of SRS. There are different types of tests performed by integration system testing. Reference [30] stated that testing aims to ensure that the developed software is free of bugs, faults, or defects and meets all requirements specified during the requirement stage. The specifications are needed to be understood by conducted initial testing at the final stage of requirements. Then, different testers [35] can avoid bias and validate requirements correctly and consistently. The user acceptance test is the last activity in the system testing. The end-users [31] usually are carried out this task to ensure the system meets their needs.

According to [32], the software development team faces time constraints to find errors through testing. Therefore, previous studies [22, 30] recommend using automated testing, reusing test cases to determine performance scalability and resource testing. In the testing phase, the program involved improvement of energy efficiency will use energy measuring instruments. The green analysis criteria are functionality and measurement. The functionality refers to all tests explained in the requirements, while the measurement evaluates the suitability of product energy consumption [35] measured and inspected during testing.

e) Maintenance Phase: The maintenance phase is associated with software operation and maintenance, which implement the product in the real environment. Software maintenance takes place if issues need to be repaired or improved [36] [37] to ensure the sustainability and quality of the product are maintained and guaranteed.

Any errors and complaints should take through electronic documentation to save time and paper during the maintenance phase. Furthermore, software archaeology, reverse engineering, and software migration are not recommended because these will contribute to the high costs and effort in execution. It is encouraged to manage knowledge among the team member effectively [22] in the development and maintenance phase to ensure a clear understanding of the system. It may reduce cost and efforts in maintenance.

Maintenance costs are high due to understanding the system and the changes that need to be analysed. Some maintenance and development contracts are separate during system development because they are kept by the company and not by the system developer. It makes it difficult for maintenance tasks and increases energy consumption if there are any changes in the system as it needs time to understand the system [34]. It is suggested by [72] that the programmer write the code that is easy and more under regular programming because if any code change is required at any stage, the correction could be done quickly. The maintenance phase could be green by including the matrices like fault tolerance, failure management, and disposal stage.

Furthermore, to reduce costs and improve energy efficiency, managers must provide training or courses to the staff to understand the old and new programming languages to speed up the maintenance process. Environmental sustainability can be supported at the implementation stage, in which program development is written for good and clear understanding by programmers. If any changes are required, the program can be easily understood, and the internal maintenance work is completed quickly, improves energy efficiency [33,71], quality and long life of the product [38].

2) Software waste: According to [39], waste management is one of the critical aspects of preserving the environment. Waste is deemed by [40] as irrelevant and has no value to production. Solid waste produces waste in the manufacturing [40] and construction [41] industries. In general, software waste is used by resources without delivering any advantage. It may contain characteristics, objects, conditions, processes, and actions in project elements. In the software domain, wastes act as friction and occur throughout the development process [42] until they produce the end of the product. The wastes need to be reduced and thus will increase efficiency in development even though the awareness and identification of waste are critical during production.

Software waste often has a problem related [43] to scope, unclear requirements, specification and design, unnecessary features and technical, team conflict, and unorganised code programming during the development process. Many researchers have been investigated software waste during the development process [27, 44-46]. These wastes are identified, such as building the wrong feature or product, mismanaging the backlog, rework, unnecessarily complex solutions, extraneous cognitive load, psychological distress, waiting/multitasking, knowledge loss, and ineffective communication in software development.

Sedano et al. [47] suggested the way to improve software engineering productivity by proposing a theory of sustainable software development that incorporates sustainability toward the principles, policies and practices into the knowledge of extreme programming. These included encouraging knowledge sharing, developing a positive attitude toward the team disruption, and considering code quality. Besides that, the policies include team code ownership, a standard schedule, and avoiding technical debt. The developers can apply good practices like test-driven development, continuous refactoring, pair programming, overlapping pair rotation, and knowledge pollination [47].

3) Green software process: Previously, the general issues in the software development process are related to time constraints, high costs, bugs and errors. But nowadays, [48] discovers that more known problems are related to people, resource and development tasks coordination and tracking.

As mentioned earlier, the software development process in a suitable environment manner and practices will lead and enhance the efficiency of the development. Sound environmental practices attempt to improve the activities that need to be implemented through software process methodology. The method of green software refers to the use of resources to meet the needs of the software with regards to the economic, social, and environmental aspects and effects. Software sustainability is considered as the ability of the software to have a longer life. In addition, the production of little waste during software development and operation [49] is one of the meanings of green software.

Sustainability and green are closely related in software engineering to ensure the long-lasting of the software in their environment. The sustainable design of the software is essential to fulfilling the user's needs and current demands.

Sustainable software refines user needs in terms of economy, society, and environment [50] in the whole life cycle phase. It concerns ensuring the long-lasting software to design, develop and deploy. From a software perspective, green is aimed to reduce the carbon footprint and negative impacts of software based on economy, society, and environment [31] during the development process. The software engages with the life cycle in green software engineering and sustainable criteria. Furthermore, Agarwal, Nath, and Chowdhury [32] proposed integrating green software development life cycle and sustainability criteria.

Sustainability supports these three main dimensions, namely economic, social and environmental. There are two different views when it comes to software. The first is sustainable software that prioritises the principles, practices, and processes that contribute to the durability of technical sustainability software. Next, [51] argues that software systems need to support other dimensions of sustainability and solve problems external to software systems. The second is software engineering for sustainability (SE4S). Both of these views are considered important as the centre of software sustainability development [53], and they need to support the five primary dimensions of economic, social, environmental, individual, and technical [52].

Generally, the economic dimension refers to capital assets or values involving capital investment, income, wealth, and profit. In contrast, the social element encompasses society, which consists of organisations and groups of people engaged in democracy, justice, employment, and social equality. The environmental dimension relates to ecosystems, climate, pollution, waste, and natural resources that can long-term impact humans and biological systems. The individual dimensions include mental and physical well-being, self-esteem, and the freedom to view human well-being as an individual. The latter is the technical dimension which involves system maintenance, infrastructure, the evolution of changing environmental conditions, and the long-term concept of system information.

B. Green Factors

The green factor is the benchmark used to assess the greenness of the software development process based on a certain standard. It should be used to ensure greenness in the software process and be applicable for future generations.

A literature study has identified green resources, people, organisational, technical, and environmental factors. From the software perspective, resource means the natural resources that must be protected from human needs and wastes. For instance, cloud computing is an alternative way to reduce energy and space in physical conditions. Meanwhile, people refer to improving the quality of human life [54] that reflects emotional health, including behaviour, thought, and action.

Organisational refers to the current need of an organisation includes leadership, employee, and performance [55]. Besides, the technical factor [56] is to cope with changes, quickly adapt to future changes, and the longevity of software systems. The environmental aspect relates to avoiding harm to the environment [57], and thus software should have minimal effects on the background during the development and maintenance process. Table I indicates the green factors and elements in the software process based on previous studies. It shows that the most popular aspects are energy efficiency, resource optimisation, environmental effect, performance, organisational support, employee support, and capacity optimisation associated with the green software process (refer to Table I).

TABLE I. GREEN FACTORS AND ELEMENTS BASED ON SOFTWARE PROCESS BY PREVIOUS STUDIES

Green factors	**Elements**	**A1** [21]	**A2** [58]	**A3** [11]	**A4** [59]	**A5** [60]	**A6** [8]	**A7** [56]	**A8** [61]	**A9** [62]	**A10** [63]	**A11** [64]	**A12** [65]	**A13** [66]	**A14** [67]	**A15** [68]	**Total**
Resource	Cost						X			X							2
	Energy efficiency	X	X									X	X	X	X		6
	Performance												X	X		X	3
	Resource usage	X														X	2
People	Personalization						X										1
	Leadership development						X										1
	Human resource			X							X						2
	Human competences										X						1
	User's perception of environmental					X											1
Organisation	Organisational Support				X				X	X							3
	Quality of Human Resource								X								1
	Employee Support			X	X					X							3
	Tool Support			X	X												2
Technical	Perdurability					X											1
	Support of shared services						X										1
	Software quality requirement						X										1
	Portability						X										1
	Modularity						X										1
	Maintainability							X									1
	Evolution							X									1
Environmental	Waste reduction					X											1
	Environmental effect		X			X						X		X			4
	Capacity optimisation					X							X			X	3
	Emission			X										X			2
	Resource optimisation		X			X				X		X				X	5

III. METHOD

During the literature study, a list of green software process factors is identified. The factors are broken down into several elements and measurements. They are used to assess the greenness compliance and level of specific software. Fig. 1 presents the flow of this research, which shows the step-by-step activities carry out in this study.

The literature study has revealed five primary green factors: resource, people, organisation, technical and environmental. The qualitative interview is designed and constructed for field expert's or academician's validation of the factors. A pilot study and content validation are carried out before the actual survey is conducted to ensure the reliability of the interview protocol. After completing the pilot study, the actual empirical study through the interview approach will be carried out. The informants are the developers, practitioners, or project managers of in-house software development companies and agencies in the public sector, which is the scope of this study.

Then, the next activity will be the data analysis. This activity will be carried out after the interview series have been completed. The data analysis will be conducted using Atlas.ti 8 software to determine the code and thematic of the interview finding. Another important task during the analysis is triangulation. Triangulation refers to measuring the reliability of the study and the extent to which it is accurate for evaluating the concept or idea. One way to conduct the triangulation is through obtaining confirmation and approval from the interviewees on the findings.

As shown in Fig. 1, this research is conducted in four main phases. The following sub-sections explain each of the phases in detail.

A. Phase 1: Theoretical Study

The first phase is the theoretical study investigating the integration between sustainability elements and waste management for software processes. The references consist of the current journals, books, and proceedings that are being studied and investigated. This phase aims to identify the types of waste and the green factors that influence the software process. It also examines issues and problems concerns to green software process from literature. The result of this phase is the theoretical framework for the Green Software Process Assessment based on Sustainability and Waste Elements. The author in [17] shows the theoretical framework.

B. Phase 2: Empirical Study

In this phase, interviews will be conducted involving software practitioners to get real input from the industry. The informants of this study will be identified and selected from software practitioners, project leaders, information technology (IT) officers, software engineers and related IT positions. They must involve in the software development process with experience and knowledge in the field of software development. The selection of informants is based on the purposive sampling technique and aims to the organisations involved in in-house software development.

This paper presents the activity in this empirical study phase. In this phase, the interview questions are designed and constructed. The validity of the content is determined through expert validation. Furthermore, we conducted a pilot study to ensure the reliability of the interview protocol. The pilot analysis is carried out and presented in this paper as the preliminary findings.

The next step in this phase will be the actual interview sessions with the identified informants. This phase will reveal and verify the influential factors in the green and sustainability software process and the current green practices in the actual software industry. In addition, software wastes formed during the software process's development and sustainability measurements will also be identified at the end of this phase.

C. Phase 3: Development of Green Software Process (Green SoftPro) Model

The third phase of this study is developing the proposed green software process model based on sustainability and waste elements. The proposed model also integrates the concepts of software waste based on inputs from theory and empirical findings. The model will identify and embed the relationship between green factors and sustainability measures that influence the greenness of software processes. In addition, the wastes specified at each phase of the software process and in line with the sustainability requirements will be considered during the model construction. The outcome of this phase is a Green Software Process (Green SoftPro) model.

D. Phase 4: Model Validation

The last phase of this research is to validate the Green SoftPro model, and the validation involves two steps. The first step is the verification by experts. The experts from the software developers and practitioners will be invited to review and validate the Green SoftPro model, which consists of green factors, elements and measurements. Further, the validation will be conducted through a case study approach. At least two software companies or government agencies will be invited to participate in the case study. The Green SoftPro model will be applied and will be validated in the actual software-industrial environment.

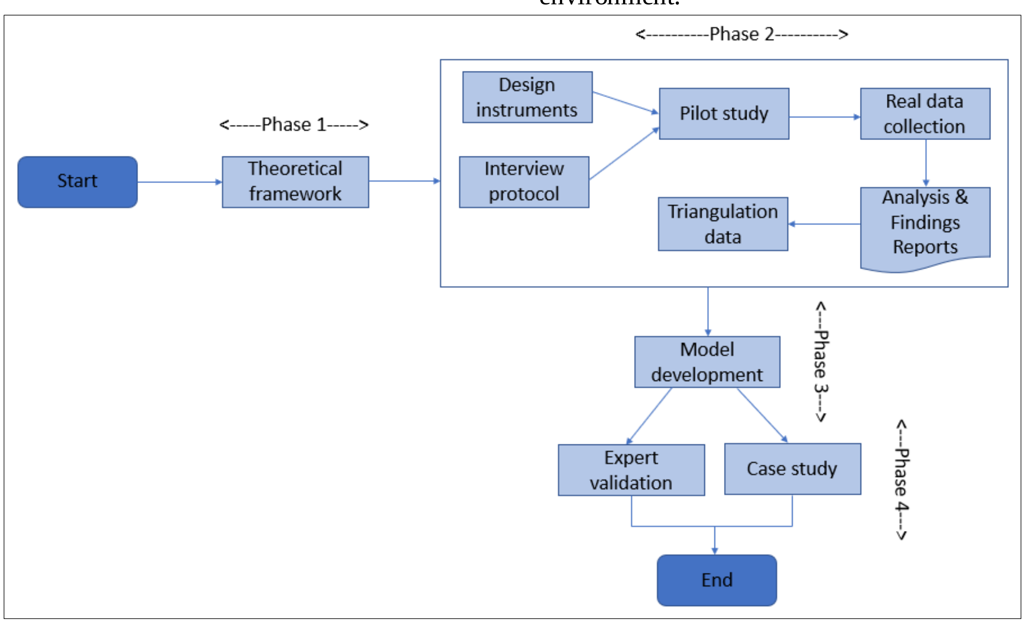

Fig. 1. Flow of the Research Activities.

IV. The Qualitative Study: Design and Pilot Analysis

This study uses the interview method to identify the current practices, issues, and challenges for green and sustainable software processes. This paper focuses on the interview protocol design and pilot study.

A. Design and Development of Interview Protocol

The interview protocol is designed based on the literature review and the proposed theoretical framework (refer to [17]). The protocol consists of four main parts, Part 1: Demographics Background, Part 2: The Practice of Green Software Process, Part 3: Waste in Software Process, and Part 4: Green Factor and Measurement for Software Process.

Table II shows the items of part 1, part 2 and part 3, which are designed in the interview protocol. And Table III shows the items associated with part 4 of the protocol that consists of the green factor and measurement. The factors are resources, people, organisational, technical and environmental.

B. Pilot Study

In qualitative research, the purpose of a pilot study is to validate and reliable the interview instruments. The pilot study was conducted in three selected organisations. The interview session was performed in 2020, and each session took about one hour during a face-to-face interview. Each of the interview sessions was recorded with permission and transcribed were analysed using transcription software. All comments and recommendations were recorded and taken into consideration.

The interview sessions in this pilot study were carried out with three software or IT experts. The selection criteria of experts are based on expertise in software engineering and, more specifically, in the in-house software development process. The duration of working experience was also considered in selection criteria where they have working experience of at least five years in the industry. The experts' working experience is based on the years suggested by [69-70]. Table IV shows the expert's background who was involved in this interview's session.

TABLE II. Interview Protocol: Part 1, 2 and 3

Section	Items
Part 1: Informant's Background	• Name of organisation • Job position • Duration of experience • Job field and expertise
Part 2: The Practice of Green Software Process	• Software development methodology used (Waterfall, Agile, Prototyping etc.) • The implementation of Standard of Procedures (SOP) or process standards • Green Practice Guidelines • Best practices for software process activities • Sustainability practices for software process activities • The benefit of green practice
Part 3: Waste in Software Process	• The understanding of software waste • Software waste in software process activities. • The solution of software waste.

TABLE III. Interview Protocol: Part 4

Part 4: Green Factor and Measurement	
i) Resource	• The usage of energy and paper • The 3R practices (Reduce, Reuse, Recycle) • The use of cloud computing
ii) People	• The improvement of human resources • Human health • Roles in software developer • Job satisfaction • Sustainability practices in software developers
iii) Organisational	• Effect/impact sustainability and green practices in organisation • Sustainability and green practice awareness among employees in the organisation • Commitment and involvement of various levels of stakeholders. • The future investment with stakeholders.
iv) Technical	• The situation of software failure • The ability to change current needs and conditional change • The adjustment to new requirements and modifications of software functions • The expectation of software operation • The adaptation of the different operating systems, hardware, and support system
v) Environmental	• The usage of video conferencing or teleconferencing platforms • The supportive of environmental • The effect of the environment during development and maintenance • The fully automated processes in software development

TABLE IV. Informant's Background

Experts	Job Description	Working Experience (Years)	Sector
A	Software developer	13	Public university
B	Software developer	12	Public university
C	Software developer	11	Government agency

V. Result And Discussion

Based on the pilot analysis, the experts recommended that some items in the protocol be improved because they believed that they were not related to the green software process. Some of the items required correction for clarification. Other than that, the expert agreed with the defined content in the protocol.

Three interview scripts were translated and analysed. The findings consist of the three main issues: current issues in the software development process, factors and elements of the green software process, and elements of software waste.

A. Current Practice in Software Process Development

Current practice in software development is an essential part of ensuring the process runs smoothly and correctly. The findings of this pilot study discover that software practitioners apply sustainability practices indirectly in the software development process; for instance, reducing paper usage, writing more effective programming code, and using online data storage space.

B. Factors and Elements of Green Software Process

The pilot findings show that the green software measurements can be identified as effectiveness, cost reduction, job creation, competitiveness, usability, participation, ecosystem, resource, protection, human health, change, adaptation, endurance, satisfaction, happiness, and skills. The pilot informants propose and agree that these elements are appropriate and applicable for measuring the green software process.

Table V signifies the finding of new green factors and their elements through the pilot study. Based on this pilot study has revealed a further aspect, namely technology. The technology factor consists of two separate elements, namely IoT (Internet of Things) and IR 4.0 (Industrial Revolution), that relate to smartphones and automation technology in future software development.

C. Elements of Software Waste

The green process can be achieved through the elimination of waste. Thus, this pilot study has identified software wastes and is consistent with the literature [27, 44]; for instance, over-requirement, design, ineffective communication, rework, lack of knowledge, and expertise. These elements of wastes may affect the software development process in terms of budget, time constraint, and duration of completion.

During the pilot study, it discovers that most informants are not familiar with the meaning of software waste. After being explained further, they admit that particular wastes during the software development process include rework, loss of knowledge, and miscommunication. However, all these problems can be solved well and effectively in the end-stage.

TABLE V. NEW FACTOR AND ELEMENT FOR GREEN SOFTWARE

Factor	Element
Resource	1. Cost reduction • Energy usage • Paperless • 3R practices (reduce, reuse, recycle) 2. Online storage
People	1. Human capital 2. Human health 3. Roles 4. Satisfaction
Organisational	1. Awareness 2. Participation 3. Top management 4. Policy & legislation 5. Culture
Technical	1. Adaptation 2. Capability 3. Compatibility 4. Endurance 5. Perdurability
Environmental	1. Environmental preservation 2. Energy saving 3. Resource-saving
Technology	1. Smartphone 2. Automation

Furthermore, the pilot study proves the reliability of the protocol and the practicality of the interview instrument. The content of the interview protocol was validated and verified. The pilot study aims to test the questions' content, identify ambiguous questions, and test responses from small selected respondents. At the same time, findings from the pilot study are used to enhance the instrument via improving the questions to be more coherent or readable, accurate, presentable, justifiable, and relevant. Moreover, the time to answer the questionnaire was also identified in preparation for the actual interview session.

VI. CONCLUSION AND FUTURE WORK

This paper has presented the literature review on the green software process, the qualitative interview design, and the pilot findings. The literature study has revealed five primary green factors: resource, people, organisation, technical and environmental. The interview protocol was designed and constructed as discussed in this paper. Later, the pilot study was conducted to test the reliability and practicality of the interview protocol. The pilot analysis discovered the initial elements associated with the green software process. The current green practices in the software development process were identified through this pilot study.

Furthermore, it also discovers the influential green factors of the software process. In addition, this study reveals the relevant software wastes which the pilot informants have identified. For future work, the actual interview sessions are to be conducted until the information obtained is saturated. The data analysis will be performed to finalise the factors, elements, and measurements that will become the Green SoftPro model development input.

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Robot Chat System (Chatbot) to Help Users "Homelab" based in Deep Learning

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***Abstract*—Homelab is a discussion platform on course materials and assignments for students and is packed in an Android application product and website. The Homelab website is built using Laravel. For Android-based Homelab application development, a special Application Programming Interface (API) with JWT security is made in this research. In Homelab, besides the question and answer feature, a virtual conversation agent (chatbot) based on deep learning with a retrieval model that uses multilayer perceptron and a special text dataset for conversations about Homelab products is also created. The virtual conversation agent at Homelab is made by utilizing the Sastrawi library and natural language processing to facilitate the processing of user messages in Indonesian. The output of this research is the response from the chatbot and the probability value from the classification results of the available response classes. The system made has an accuracy rate of 96.43 percent with an average processing time of 0.3 seconds to get a response.**

Keywords—API; Chatbot; deep learning; Homelab; question and answer forum

I. Introduction

Homelab is a question and answer forum platform (website and Android application) specifically for students who want to ask questions about college assignments. Homelab services can be used specifically for students in Indonesia. Homelab maps several majors and courses that are suitable for students. Overtime after the release of this product, many users are still confused about reporting bugs from the product and using features. Starting from that problem, by collaborating with the Homelab team, the initiative was taken to add a feature to guide users automatically based on text messages by using the chatbot feature to solve this problem.

A chatbot is a dialogue system between humans and machines combined with natural language and artificial intelligence [1]. Chatbots who trained by using artificial intelligence and natural language processing can act as intelligent systems where chatbots can answer questions given to them by their users [2]. Chatbots that use machine learning need to understand the context and input from the user before formulating an appropriate response to the user [3]. Generally in digital industries, chatbots are often used to respond to customer conversations about company products and some of problems that occur. The use of chatbots in companies can save costs and save more times.

Chatbots in large companies are often combined with their existing data centers so that they are more optimal in providing integrated data processing and response. Chatbots have the ability to respond to users more quickly than chat with customer service [4]. With this research, chatbots are combined with deep learning using a chatbot retrieval model with the Multilayer Perceptron (MLP) learning method combined with Natural Language Processing (NLP) so that they can understand what Homelab users are looking for. AI chatbots can analyze data better than humans to more accurately predict each customer's risk, thereby giving customers the right amount of money [5].

In this paper, a text chatbot feature, named Lixa, is implemented into Homelab application to help users understanding the application and guide them on using the application. Lixa is chosen to be a retrieval-based model chatbot as this type of chatbot can give much faster responses compared to a generative based model. The chatbot uses multilayer perceptron combined with a special text dataset to help it conversates with users smoothly. The results and conclusions are discussed in the end of this paper.

This paper is divided into seven sections. The first section, which is this part that you have already read, contains some brief introduction about the problem and motivation of this research. Section II explains about background and some works which is related to this work. Section III contains about the overview of the system and the design of the solution to the problem. Section IV is a part that gives explanations of the testing procedures and the results of the testing. Section V is a discussion part about this work and the results from previous section. Finally, Section VI and Section VII draw the conclusion and future works that can be done related to this problem.

II. Background and Related Work

The usage of chatbots in daily life has increasing quite dramatically in the last decade [6]. Various domains of human's life are affected and getting easier with the help of chatbots. The rise of personalized bot assistants integrated into daily device, such as Alexa, Cortana, and Siri, is one of them. In educational sector, the performance comparison between various engines are already done [7]. Another example of chatbots usage that made life easier is on answering commonly asked questions by using neural networks [8]. By implementing chatbots, real human can focus on doing more important things rather than answering repeated questions asked by different persons.

Deep learning is an implementation of machine learning that learns at various levels, according to different levels of abstraction and using artificial neural networks [9]. Deep learning differs from traditional machine learning because deep learning performs representations of data such as images, videos, or text without introducing specific code or domain rules. The advantage of deep learning is that it transforms data from non-linearly to linearly through transformations (hidden layers). In addition, deep learning is also able to find non-linear decision boundaries, as well as simulate non-linearly interactions [10].

Deep learning helps the chatbot system to understand some information from the user and can improve its accuracy compared to using a rule-based chatbot [11]. But deep learning chatbots have a weakness; it needs a lot of data representation to give accurate responses to the user [12]. The most important thing about creating chatbots is that chatbots can understand and discuss with users, no matter how the user type their messages. One method that can be used to help chatbots understand the message from user is by splitting the message word-by-word. A method was developed to implement word splitting introduced by Mohammed Javed et al [13]. After the algorithm performs word splitting and character count, including all types of words and special characters, then the algorithm works according to the number of words in a sentence. The word gap can determine the average gap between words. If the words used are in the group of words that are counted on the dataset, then this word set can be defined as non-empty words, this leads to tokenization of empty spaces between words. Word separation can be realized using the Natural Language ToolKit (NLTK). This was proposed in a study by Naeun Lee et al [14].

Deep learning chatbots can be divided into 2 types: a retrieval-based model and a generative-based model. A retrieval-based model uses a predefined repository of fixed responses and several types of categorical contexts to select appropriate responses based on patterns. The system doesn't generate new text, they just select responses from a fixed repository. This type of model issues the answer with the highest score. A model system combined with deep learning techniques to provide more accurate responses [15]. Unlike retrieval-based model, a later one does not depend on a fixed response repository. In a generative-based model, the chatbot generates new responses using the results of the analysis of previous conversations. The responses generated are based on deep learning and training. Learning process of this model really takes a long time and a lot of resources. This model is very rarely applied and the results of the responses issued are very difficult to predict [16].

III. System and Design Overview

A. System Overview

An overview of the overall development of the Homelab website can be seen on Fig. 1. In this picture, it can be seen that the chatbot process is carried out on different sites. This is done because of language differences in website development. The chatbot website uses the Python programming language with the support of the FastAPI framework while the Homelab website uses the PHP programming language with the Laravel framework support. The Homelab application development on Android gets REST API support from the Homelab website. To secure the API path, the JWT security between the Homelab website and the Android application is also added.

Fig. 2 shows the overview of how the chatbot works, starting from the API request stage up to the API response message. The detailed explanation of each processes is as follows:

- Message From: the process of receiving messages in the form of JSON data from the Homelab website.
- Pre-processing: at this stage, the data will be processed using various techniques, such as case folding, stemming, and tokenizing.
- Bag of Words: in this process, the data (words) that have been cleaned (normalized) will be given a weighted value for each word.
- Prediction Label: in this process, the data that can be processed in the model will be predicted to produce the related class and the highest probability achieved from several classes.
- Response Message: at this stage is looking for answers from the dataset (Response Attributes) according to the highest probability and related classes.

The deep learning website receives a request from the Homelab website in the form of message input, which will then be processed by pre-processing using case folding, stemming, and tokenizing so that it becomes a data description in the form of a bag in simplified Indonesian. Furthermore, the embedding process uses a bag of words where the words that have been separated in the tokenizing process are in the form of an array of 1 or 0 if the data is available or exists.

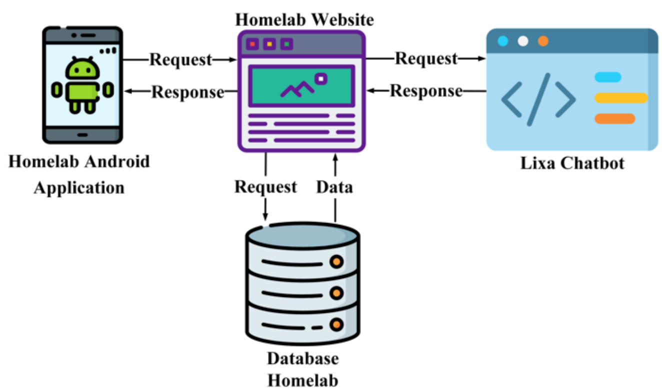

Fig. 1. An Overview of the Homelab System.

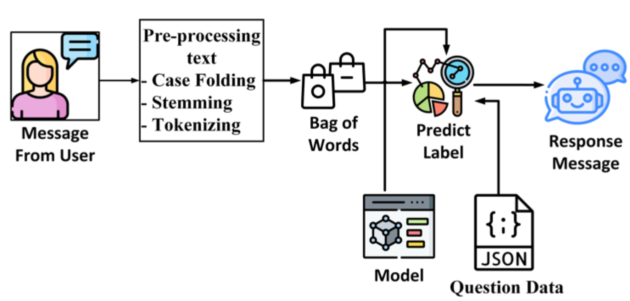

Fig. 2. An Overview of Processes Involved in Chatbot System.

B. Dataset

The response pattern data used has been adapted to several cases and Homelab products. The response attribute is made with the Subyek-Predikat-Obyek (S-P-O; or Subject-Verb-Object in English) sentence pattern and some keywords in Indonesian so that it can suit the needs of using Homelab. The chatbot dataset is designed using 99 contexts/classes of response forms, 367 patterns, and 242 different sets of words with the pattern shown in Table I. For database needs on the Homelab website, MySQL Homelab data is used. In addition, the Homelab website also uses MySQL to store tracking data so that it can be displayed on the website.

C. Preprocessing

Fig. 3 shows an overview of the preprocessing step of the text data. Text data is preprocessed before conducting training and making deep learning models. Tokenizing is one of the basic things that can be done by using NLTK. Tokenizing process is done on preprocessed text data which aims to break down data into smaller words. Case folding process is done to lowercase all letters and remove some punctuation marks, such as '!' and '?'. Since prefixes and suffixes are used very often in Indonesian, all words need to go back to their basic form, which is the goal of the stemming process: reduce all words into their basic form. The stemming process is done by using the Literature library which will decipher Indonesian words [17].

D. Feature Extraction

Feature extraction is a step to assign a weight value to each words. In this work, the Bag of Words (BoW) feature extraction is used. BoW is a simple representation used in natural language processing and is also known as a vector space model. A text in the form of a collection of words or sentences can be represented as a bag regardless of the word order and language used but can maintain differences between words or sentences. BoW models each document by counting the number of occurrences of each word that occurs [18]. If the word in the list appears, it will be given 1. And if the word is not appear, then the data will be given a value of 0.

E. Modeling

The results from the previous stage (preprocessing and feature extraction) are then processed in a classification method using a neural network with a feed-forward architecture, namely Multilayer Perceptron (MLP). The neural network is composed of several layers consisting of one input layer, several hidden layers, and one output layer. The illustration of neural network architecture can be seen in Fig. 4. Multilayer Perceptron uses a supervised learning technique, namely back-propagation for training [19]. This method is a deep machine learning method that represents how the human nervous system works at understanding complex tasks, such as in computer vision [20] and natural language processing [21]. The system has multiple inputs and multiple output classifications and consists of a large number of connected processes. The chatbots are trained on author-designed data sets, which store question patterns according to product requirements, responses, and category context. The model used in deep learning in this study is a sequential representation layer to help learn hierarchical or multilevel features. The architecture used in this model is a feed-forward type, so that information moves forward in the model used. The MLP model is interpreted mathematically as follows:

$$Output\ (O_j) = \sigma\left(\sum_{k=1}^{k} x_k w_{k,j} + \beta_j\right) \tag{1}$$

$$v_i = \sigma\left(\sum_{k=1}^{k} x_k w_{k,j} + \gamma_j\right) \tag{2}$$

where w is used as learning parameters, γ represent noise or bias from the model, k is the number of input units, and j is the number of hidden units that use the activation function. The activation function used in this model is ReLU non-linear activation. Several hidden layers are useful for faster learning. The output layer uses the softmax activation function to provide a probabilistic interpretation and generate multi-class outputs. The softmax activation function can be written as:

$$Softmax(z_L) = \frac{e^{z_L}}{\sum_{k=1}^{k} e^{z_k}} \tag{3}$$

TABLE I. ATTRIBUTES TO THE RESPONSE PATTERN

Attribute Name	Description
Tag	Class is used as a label by the model to search for related responses.
Patterns	The pattern of the user to ask questions related to the existing class.
Responses	Response is the answer from the chatbot to the user. Responses are predefined for each class.
Context	Context is used to be a reference for the backend of the website for certain purposes.

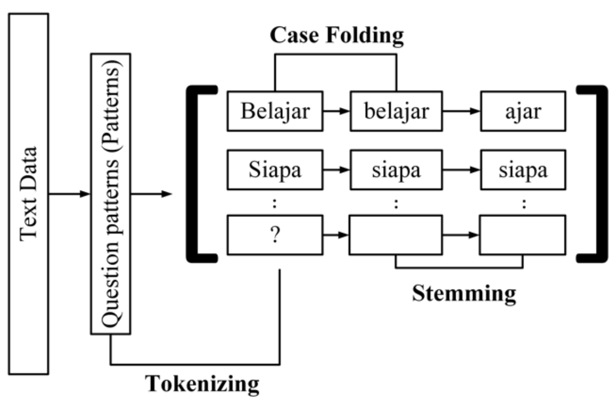

Fig. 3. Preprocessing Process Examples on some Words in Indonesian.

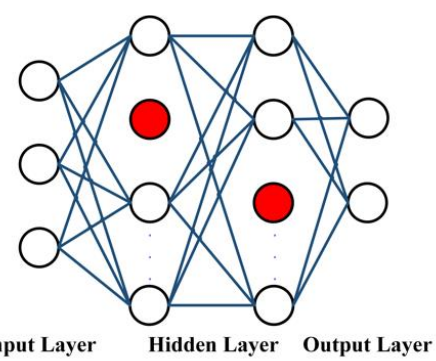

Fig. 4. Neural Network Architecture Illustration with Dropout.

where k is the symbol for the number of output classes generated at softmax, z_L is the vector value of L with L is the output layer containing the number of neurons. The model used in the chatbot system is a type of word classification, so the system uses a cross-entropy function in the network. Cross-entropy uses the following mathematical equation:

$$CrossEntropy = -y\log(\hat{y}) - (1-y)\log(1-\hat{y}). \quad (4)$$

At the training or modeling stage of the chatbot, there is also an optimizer. Optimization is an algorithm that is used to update and calculate the exact and optimal value of the model parameters to minimize the loss in the neural network.

F. Get Response

At this stage, after doing the modeling, the chatbot system will make predictions on the message that is input using the model that has been created. The output of the prediction is the order of labels and the weights of the response labels. The label will be used to search for responses that match the label and one of several responses will be chosen at random. The selected response will then be forwarded and displayed to the user.

IV. Testing and Result

A. Optimizer

The scenario in optimization testing aims to find a comparison of the accuracy of the optimizer by comparing 4 optimizers (Adam, SGD, Adagrad, Adamax). In this scenario, Adamax, Adagrad, Adam, SGD used a learning rate parameter of 0.02 and an epoch of 200. The test was conducted using Indonesian language and Sastrawi libraries. The loss of the model with different optimizers can be seen in Fig. 5.

Another test is also done to check whether the response message from the chatbot corresponds appropriately to the question asked by the user. In this test, three cases with different questions are given to the chatbot. The first question is "kamu siapa?" which means, "who are you?", labeled as Q1. The second question is "apakah kamu tahu tentang poin?" which means, "do you know about points?", labeled as Q2. And the last one is "apakah kamu berbohong?" which means, ""are you lying?" and labeled as Q3. The accuracy and relationship of the responses are measured. Here, the relationship means whether the response is appropriate or not related to the given question. The results of this test can be seen on Table II.

From the test results, it can be concluded that Adamax tends to read the available patterns in the responses. This is proven when the test with question "apakah kamu berbohong?" which is not included in any context in the repository is read as an empty message and immediately redirected reception to an unintelligible context with high accuracy values.

B. Epochs

The epochs parameter testing scenario aims to prove the effectiveness of the number of epochs on system accuracy. Epochs are the number of stages required for the system to carry out the training process. The epochs parameter test uses the message "did you know about purchasing points?". The epochs that were tested for the first time used the default epochs value of 200 epochs with a learning rate of 0.02. The number of epochs tested are 50, 100, 150, and 200.

The result in Fig. 6 shows that the accuracy of the system is increasing as the number of epochs increases. The highest level of accuracy, which is 99%, is obtained with the number of epochs as much as 150 and 200. This is because as the number of epochs increases, the chatbot system will learn to reduce the error value and learn to increase the accuracy value more. But in the deep learning algorithm there is such a value called a saturation value. If it has reached the highest accuracy value in certain epochs, then the next epochs tend to have stable accuracy. Here, 99% accuracy in 150 epochs seems to be its saturation point.

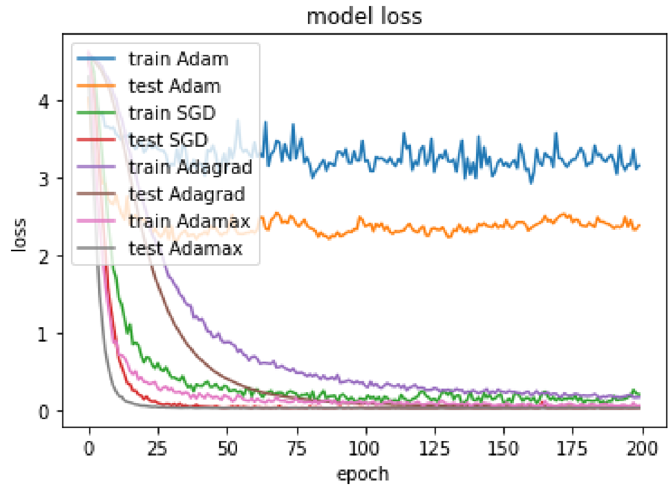

Fig. 5. Loss of the Model vs Number of Epochs on Various Optimizer.

TABLE II. Optimizer Test Results

Q	Optimizer							
	Adam		*SGD*		*Adagrad*		*Adamax*	
	A	***R***	***A***	***R***	***A***	***R***	***A***	***R***
Q1	-	N	89.6%	Y	79.9%	Y	98.3%	Y
Q2	25.6%	N	36.9%	N	92.1%	Y	98.1%	Y
Q3	-	N	83.7%	N	86%	N	85.76	Y

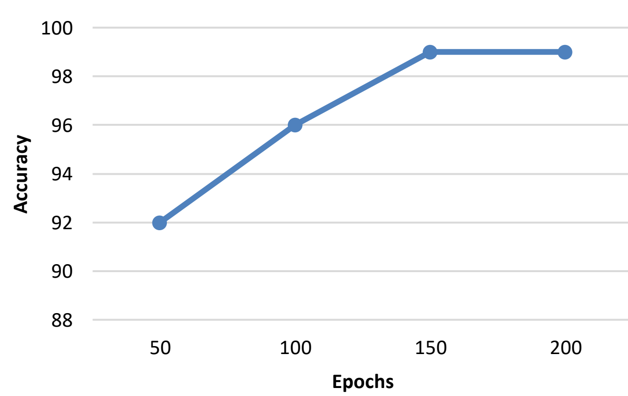

Fig. 6. The Accuracy of the System vs the Number of Epochs.

C. Learning Rate

The learning rate parameter testing scenario aims to prove the effectiveness of the number of learning rates on system accuracy. Learning rate is the level of system accuracy to correct the error value or to minimize the loss value. Testing the learning rate parameter using the message "apakah kamu tahu tentang pembelian poin?" which means "did you know about purchasing points?", as well as the number of epochs that gives the maximum accuracy value. The learning rates tested are 0.1, 0.01, 0.02 and 0.001. The number of epochs used is 200 since it gives the maximum accuracy from previous test. The optimizer used is Adamax. This optimizer is used because the results of optimization testing when Adamax optimizer is used are very good.

Fig. 7 shows the results of the learning rate test. The graph shows the effect of the learning rate value to the accuracy of the system. The highest accuracy level is obtained with a learning rate value of 0.1, 0.02, and 0.01, namely 99%. This is because the smaller the value of the learning rate, the greater the accuracy to reduce the error value in the system. But it will increase the training process time and require a larger number of epochs to reduce the loss rate to convergent so that the loss value decreases.

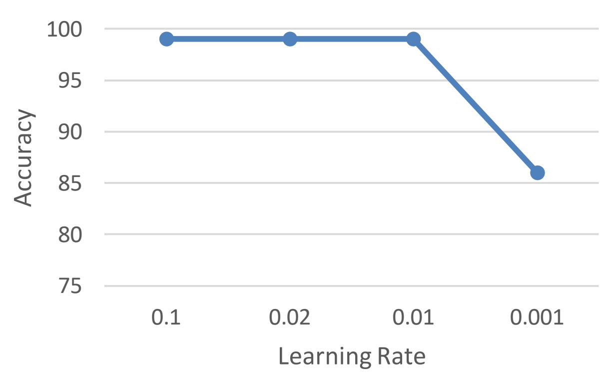

Fig. 7. The Results of the Learning Test.

TABLE III. CHATBOT RESPONSES SPEED TEST RESULTS

User Message	Time (s)	Accuracy	Response
Kamu Siapa?	0.13	100%	Kamu bisa memanggilku Lixa.
Apakah Kamu tahu tentang poin?	0.12	100%	untuk informasi poin silahkan kunjungi alamat ini : askhomelab.com/informasi_poin
Apakah Kamu berbohong?	0.04	99.53%	Maaf Lixa masih belum mengerti dan terus belajar, semoga pertanyaanmu selanjutnya terjawab ya..
apakah kamu tahu tentang pembelian poin?	0.06	100%	untuk informasi poin silahkan kunjungi alamat ini : askhomelab.com/informasi_poin
saya punya keluhan tentang poin pembelian yang belum masuk.	0.04	99.70%	lixa akan membantu menyampaikan keluhan kamu kepada admin, silahkan tulis keluhan anda

D. Response Speed

This test scenario uses the Adamax optimizer parameter with the learning rate value is 0.02, and number of epochs is set to be 200. The response speed testing scenario on the system is carried out to measure the response speed of the chatbot system. The process of calculating the speed of chatbot responses is done by calculating the average value of the total time obtained to receive responses from bots on each message. The test is carried out by sending 5 different messages on the chatbot site through the API. The test uses Indonesian input with the Sastrawi library. The results can be seen on Table III. The equation to calculate the average can be expressed as follows:

$$Average = \frac{\sum_{i=1}^{5} t_i}{N} \tag{5}$$

The system gets an average time of 0.3 seconds and an average accuracy of 96.43% for each given message. This is because in the process of giving responses there is no need to retrain and can shorten the user's time to get messages. The system only needs to make predictions from the model that has been made and look for responses according to the storage area.

V. Discussion

Traditional conversation services to customers often emphasize the need for excessive information on users, besides that traditional conversation to users often take a lot of time and cannot be served 24 hours. Therefore, the chatbot system was created to respond to several things regarding the product and user needs that have been designed.

Therefore, this study examines the addition of deep learning to chatbots that are useful for conducting rapid evaluation and analysis of data collections and questions from users. Its main objective is to study neural networks and the role of chatbots in providing appropriate responses. In this study, the author examines the chatbot retrieval model that can focus on answering only about the features of the Homelab product. This model utilizes the weights of the predicted words and retrieves the answers in a dictionary of questions.

VI. Conclusion

Chatbot can be used to interact with users. The development of a retrieval-based model chatbot can help Homelab users get appropriate responses related to their questions. This study found that a chatbot with a retrieval-based model using a multilayer perceptron neural network at Homelab can respond to the questions according to the stored response pattern that has been created. The chatbot system can respond using a multilayer perceptron artificial neural network well in several text message tests with response pattern storage containing 367 different patterns in 99 contexts or classes. Because the chatbot system is based on a retrieval model, there is some context outside of stored response patterns that chatbot could not answer well. The chatbot system achieves the highest accuracy with the number of epochs is set to be 200 with Adamax optimizer and the learning rate value of 0.02 on response context data training so that it gets 96.43% accuracy.

However, from the statement above, we know that the retrieval chatbot created in this study has the ability to answer faster than the traditional way and is more accurate in providing answers to the topics that have been provided. Besides that, this chatbot also has drawbacks including this chatbot is not able to respond appropriately to topics other than those already provided in the database. The chatbot also has ambiguity in some of the words that have been provided due to incorrect word pairs.

VII. Future Work

Future work will focus on further analysis and research on word processing from user input and enabling chatbots to determine answers using answers from previous users (Generative-Chatbot Model). The Generative Chatbot model will process data every time from those who have used it, where the data is processed by deep learning to produce the right response predictions. Of course, this model really takes a lot of time and a lot of users too.

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Optimized Energy-efficient Load Balance Routing Protocol for Wireless Mesh Networks

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***Abstract*—Wireless mesh network (WMN) technology gains the user attractions due to its deployment flexibility. The main challenging task in the WMN is the provision of Quality of Service due to its unbalanced traffic in communication. Moreover, the recent advancement in wireless technology has fueled the user's attraction towards the delay-sensitive services, which in turn additional impact on WMN to provide QoS. The paper aims to provide the QoS in the WMN by load balancing, and energy efficiency. In literature, various mechanisms have been designed to address the issue, but they fail to achieve the optimal solution in terms of throughput and energy efficiency. Thus, the work aims to design the energy-efficient load balancing routing metric to address the limitations of existing conventional methods. Load balancing is accomplished by the selection of non-congested nodes, and energy efficiency is attained by the selection of the greatest packet processing capable nodes for communication. Both non-congested and greatest packet processing capable nodes are used to compute the route between source and destination. The performance of the proposed routing protocol is analyzed by network simulator and the results outperformed in comparison with recent existing methods.**

Keywords—Wireless mesh network; routing; energy efficiency; optimization

I. Introduction

Wireless mesh networks (WMNs) technology [1] is the advancement of mobile ad hoc networks [3] that aims to provide greater bandwidth and less cost communication services to the users. WMNs are composed of mesh clients, routers, and gateways, where routers interconnect one another through a mesh topology [1] and communicate in a multi-hop manner [3]. The mesh clients in WMNs communicate in a peer-to-peer manner [3]. The mesh clients are user apparatus, and they are connected to the internet via mesh routers and gateway, where the gateways are special types of routers. The Fig. 1 shows the WMNs architecture.

The characteristics of WMNs are cost effective, fast deployment, and greater bandwidth, these characteristics have been attracting the users to select this technology for communication. However, one of the major challenges in WMNs is to provide QoS communication. The reason behind this limitation is unbalanced traffic and further this technology is not designed to work effectively in a congested environment. Thus, some of the nodes in the network take heavy traffic than the other nodes and cause the congestion, and it is known as unbalanced traffic distribution. It causes the packets drop in the network at routing layer, which interns negatively impacts the system performance in terms of energy efficiency, delivery of packets, and QoS. The paper aims to design the routing protocol to avoid the packets drop at network layer.

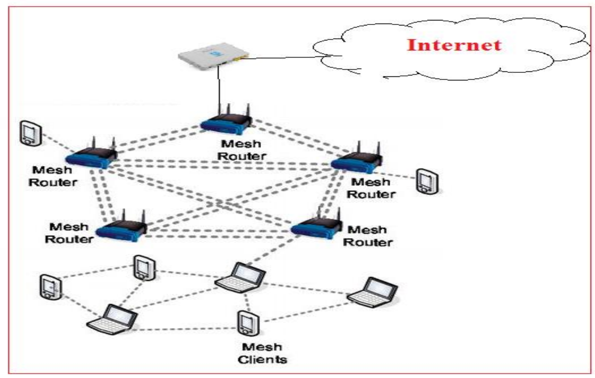

Fig. 1. Wireless Mesh Networks Architecture.

II. Literature Review

In literature, various routing mechanisms have been designed to adder the issue of unbalanced traffic distribution in WMN by traffic re-routing [1]. However, they do not consider the load status at the node buffer. Thus, the queue at the some of the mesh nodes buffer increases and causes the congestion and further negatively impact on the overall network performance.

A selective load balancing (ViLBAS) [5] technique is designed to address the congestion at mesh nodes during video delivery. This technique enhances network performance in terms of packet delivery. However, it is not designed for all delay-sensitive traffic conditions. Similarly, an efficient load balancing routing protocol designed by work [6], to achieve the QoS in terms of network lifetime, minimum delay, and guaranteed bandwidth. Work [7] finds that the VILBAS [5] and work [6] are not attained effective load balancing in WSN. The work [8] designed the Load balanced coding aware multipath routing to balance the traffic in the network. The performance results show that the work [8] achieves the load balancing efficiency with increased routing overhead, delay, and energy consumption. The work [9] designed the interface shifting or load balancing method to resolve the problem of energy consumption along with load balancing.

A review of various mechanisms developed for load balancing and energy efficiency was analyzed in work [6] and concluded that there is a requirement of the routing protocol which needs to attain the energy efficiency with load balancing to provide the QoS in WMNs. Thus, the aim is to provide the QoS in the WMN by load balancing with energy-efficiency. The major contributions of the work are as follows:

1) Load balancing in WMN is achieved by considering the queue constructed at node buffer due to the network layer.

2) Energy efficiency is achieved by considering the packet processing ability of node concerning residual energy.

3) The selection of the route between communication entities by maximizing the Energy efficiency and avoiding the congestion.

The reminder of the paper is organized as follows.

Next section describes the Load Balancing in WMNs by computing queuing at network layer, further section explains with Energy efficiency by packet processing ability of the nodes. The proposed energy-efficient load balance routing for multi-radio WNNs is explained in Section 5. The paper ends with conclusion followed by future work.

III. Load Balancing in WMNs by Computing Queuing at Network Layer

Load balancing in communication network is the procedure to distribute the traffic load across the multiple entities [18]. Load balancing approach is used to enhance the network performance and avoid the congestion. In WMNs multi path routing is a common approach, and thus the load balancing is achieved by the process of traffic rerouting form congested entities to uncongested entities. In literature, traffic rerouting is achieved by various routing protocols by different metrics [1]. However, they fail to address the congestion at the node buffer, which negatively impact on the overall network performance.

To extend the performance of load balancing routing algorithms designed for delay-sensitive traffic such as voice, video, and multimedia in WMNs, novel load balancing algorithm designed based on the queuing delay [2]. The algorithm detects the nodes with less queue at its network layer and based on it the algorithm assigns the traffic to the nodes for transmission [10]. The routing metric designed based on the queue at the MAC layer of the node is not sufficient to achieve the QoS for delay-sensitive traffic transmission in WMN. There is a possibility in the network that the packets queued at the network layer of the node buffer, and the delay caused by it is more impact on the network performance in comparison with the delay caused by the MAC layer queue [14]. Thus, to decide the node status regarding its load, the queue at network layer needs to be calculated.

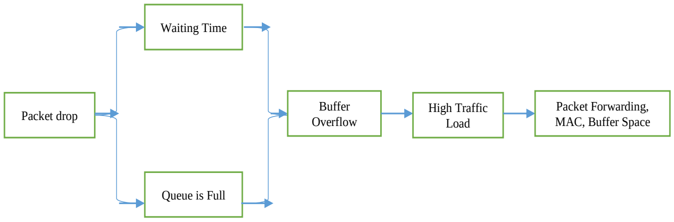

Fig. 2. Packet Drop from Node due to Buffer Overflow Reasons.

Various congestion detection and prevention mechanisms have been designed at the transport layer to overcome the problem of load balancing due to queuing at node buffer [4]. These algorithms are performed well for the wired network, and wireless-infrastructure based networks and cannot directly be applied to the WMNs [3]. Thus, the early congestion prevention algorithm i.e., the queue computation at network layer is needed to overcome the problem of load balancing queuing at node buffer. The load at the node buffer increased due to exceeding high traffic load that is associates with the data forwarding and medium access control [15, 16], and it is shown in Fig. 2. Thus, the traffic load of the nodes needs to be computed at the network layer and according to that the assignment of traffic load. The proposed work computes the queue at the network layer of the node to decide the node status regarding its load. The number of packets is queued at network layer of the node is computed by equation (1).

$$\text{Averagenewqueue}(Q_{avrg}) = \text{Instant Queue} * (\text{Weighted constant}) + (1 - \text{Weighted constant}) * \text{Avergeoldqueue} \quad \text{.........(1)}$$

Work considers that every node contains the RED gateway [13] to compute the average queue length of its buffer. It is a low pass filter work on the principle of the exponential weighted moving average. The procedure to calculate the average queue decides the grade of burstiness that would be permitted in the gateway queue. Instead of taking maximum values, we consider the average to prevent the packets drop in advance by setting threshold value, as average queue size above the current threshold. The weighted constant value of equation 1 is computed by low-pass filter time constant value [17] of RED gateway. Threshold value at the network layer queue is computed by equation 2.

$$Thresholdbuffer(Q_{Th}) = 75\%\ of\ buffer\ size \quad .(2)$$

If the node Averagenewqueue (Q_{avrg}) of the node is above the threshold queue (Q_{Th}) value, then the node cannot handle further traffic, and known as congested nodes. The proposed algorithm i.e., node selection algorithm shown in Fig. 3 detects congested nodes and avoid them to participate in the communication.

Algorithm 1:- Node selection algorithm

Procedure to computing the current residual condition of nodes $(Q_{avrg}, Q_{Th}, EP, E_{Pth})$
{ Compute the Q_{avrg} from equation 1
if $(Q_{avrg} \leq Q_{Th})$
{ Then compute the E_P from equation 4
if $(E_P \geq E_{Pth})$
node participates in routing
else node does not participate in routing }
else Node does not participate in routing }

Fig. 3. Node Selection Algorithm based on the Congestion and Energy Efficiency.

IV. ENERGY EFFICIENCY BY PACKET PROCESSING ABILITY OF THE NODES

Considering energy for route computation is an active research topic in WMNs, as the nodes in the network are equipped with heterogeneous resources, and they need to act as a router for multi hop communication. To act as router, the node needs to spend its energy to accomplish the routing task. Recent survey shows that that node needs to spend 800-1200 MW of power to receive and transmit the packets [19]. To address the issue, the routing protocols design must consider the energy issue in their routing process. In literature, different routing protocols have been designed to achieve the goal of extension of energy conservation [20]. These protocols broadly categorized as link stability routing, network lifetime extension routing, and energy aware routing. The recent work [21], analyzed these routing protocols, and concluded that they depute the particular path for communication, which leads to heavy traffic towards the nodes, and causes the node to expire due to energy drainage, and drops the packets.

The performance of the WMNs can be enhanced by reducing the packet drop due to the rapid increment of the energy drain of the node. Thus, paper computes the packet processing ability of the node regarding its residual energy and traffic at its node buffer.

Consider all the nodes available in a network consist of energy (E) to process the packets, as nodes in a network act in a peer-to-peer manner. The energy (E_{pi}) is spent by the node to process the one packet P_i, which includes packet reception, processing, and transiting energies. Then the residual energy $(E_r)$of the node is calculated as follows, by equation (2).

$$E_r = E - E_{pi} \tag{3}$$

The residual packet processing ability (E_P) of the node during the time interval (t) is computed as follows:

The residual packet processing ability of the sensor node in its available energy is computed by the following equation 4.

$$E_P = \frac{E_r}{(E_{pi}(t))}\ \forall\ \boldsymbol{E_r} \geq\ (E_{pi}(\boldsymbol{t})) \tag{4}$$

The threshold residual packet processing ability of the node is calculated by following equation 5.

$$E_{Pth} = \frac{(75\%)*E}{(E_{pi}(t))} \quad \text{……………..(5)}$$

If the nodes' residual status of packet processing ability concerning energy is higher than the threshold i.e., E_{Pth} from equation 6, then the node is considered for communication. The algorithm to consider the node for communication is explained in Fig. 3.

$$Q_{thm} = \left(\frac{h}{2}\right) * Q_{th} \quad \text{……………..(6)}$$

Where,

$h = hop\ count\ from\ source\ to\ destiantion$

Q_{thm}
$= acceptable\ threshould\ for\ considering\ the\ node\ for\ routing$

V. ENERGY-EFFICIENT LOAD BALANCE ROUTING FOR MULTI-RADIO WNNS

Paper considers the WMNs with mobile nodes distributed in the network communication area. The source node wants to communicate with destination through the routing path which must be less congested and energy-efficient to achieve the QoS in communication by enhancing the packet delivery and lifetime of the network. Thus, the paper develops the energy-efficient load balance routing protocol for WMNs to select the route with the greater energy-efficient and less congested node for computing the routing path, to enhance the QoS of the network.

The designed routing protocol is an extension of the existing AODV [11] routing protocol. Whenever the source wants to interact with the destination and finds that there is no routing entry is available in the routing-table. Then the source broadcasts the route-request message to compute the route. An intermediate node receives the request message then it checks its average queue by equation 1 and compare it with the threshold queue size equation 2, if it satisfies then it participates in routing otherwise it discards the routing packet. If it satisfies with threshold queue size, then it computes the packet processing ability in terms of energy by equation 4 and compare it with the threshold value of packet processing ability, if it also satisfied then rebroadcasts the route request packet. The same procedure will follow until the route request message reaches the destination. Destination examines all the route request merges received from different intermediate nodes and compute the route as follows.

A. Routing Path selection by Destination node

The previous sections explain the concept of nodes to participate or non-participate in the routing by average queue size and packet processing ability of the nodes. Now the nodes need to be finalized for routing path from source to destination, the total acceptable queue size for routing path is about Q_{thm} , and it is computed by the following equation.

Each node n_i has Q_{avrg_i} queue size at its node buffer and having the E_{P_i} of residual status of packet processing ability to process the packets. One can avoid the congestion and enhance the energy efficiency in the network, by following considerations:

1) The total queue size of the routing path nodes must not exceed the value of Q_{thm}.

2) The total residual status of packet processing ability of the routing path nodes as much as possible.

To select the nodes for routing path by satisfying above conditions, the work considers the following tuples and considerations.

1) $\langle Q_{avrg_1}, Q_{avrg_2}, Q_{avrg_3}, \dots\dots Q_{avrg_n} \rangle$ and $\langle E_{P_1}, E_{P_2}, E_{P_3}, \dots\dots E_{P_n} \rangle$.

2) $Q_{thm} > 0$, and work wish to determine the routing path nodes $T \in \{n_1, n_2, n_3, \dots . n_n\}$ such that;
$Maximize\ \sum_{i \in T} E_{P_i}$,

And subject to $\sum_{i \in T} Q_{avrg_i} \leq Q_{thm}$

In order to solve the problem of selecting the routing nodes for routing path, work decomposes the problem by constructing the two-dimensional array, as follows.

$V[0 \dots n_n, 0 \dots . Q_{thm}] \, \forall \, n_1 \leq n_i \leq n_n$ and $0 \leq Q_{avrg_i} \leq Q_{thm}$

The entry of the array $V\left[n_i, Q_{avrg_i}\right]$ is going to select the nodes $\{n_1, n_2, n_3, \dots . n_n\}$ by maximizing the packet processing ability and by not exceeding the value of Q_{thm}. The array entry $V\left[n_n, Q_{avrg_n}\right]$ provides the routing path nodes which are going to maximize the packet processing ability of the routing path by not exceeding the value of Q_{thm}. Work selects the entries of the array $V\left[n_n, Q_{avrg_n}\right]$ by avoiding following conditions:

1) $V\left[n_i, Q_{avrg_i}\right] = max\left(V\left[n_i - 1, Q_{avrg_i}\right], E_{P_i} + V\left[n_i - 1, Q_{avrg_i} - Q_{avrg_i}(n_i)\right]\right)$ $\forall \, n_1 \leq n_i \leq n_n$ and $0 \leq Q_{avrg_i} \leq Q_{thm}$

2) $V\left[0, Q_{avrg_i}\right]$=0 $\forall \, 0 \leq Q_{avrg_i} \leq Q_{thm}$

3) $V\left[n_i, Q_{avrg_i}\right] = -\infty \, \forall \, Q_{avrg_i} \leq 0$

To select the entries of the $V\left[n_n, Q_{avrg_n}\right]$, work uses the knapsack algorithm [22], and explained as follows;

Knapsack$(\boldsymbol{E_p}, \boldsymbol{n_n}, \boldsymbol{Q_{thm}}, \boldsymbol{Q_{avrg}})$

{

For $(Q_{avrg} = 0 \; to \; Q_{thm})$

$V[0, Q_{avrg}] = 0$

$for(n_i = n_i \; to \; n_n)$

For $(Q_{avrg} = 0 \; to \; Q_{thm})$

$if\left(Q_{avrg_i}(n_i) \leq Q_{avrg}\right)$

$$V\left[n_i, Q_{avrg_i}\right] = max\left(V\left[n_i - 1, Q_{avrg_i}\right], E_{P_i} + V\left[n_i - 1, Q_{avrg_i} - Q_{avrg_i}(n_i)\right]\right)$$

Else

$V\left[n_i, Q_{avrg_i}\right] = V\left[n_i - 1, Q_{avrg_i}\right]$

$returnV[n_n, Q_{thm}]$

}

The route replay message unicast by destination through the computed path. The rest of the activities of the routing process such as sequence numbering, flag, and timer setting follows the existing routing protocols AODV [11].

VI. Performance Evaluation

The performance of the designed routing protocol is analyzed with network simulator [12]. The simulation environment and parameters for the performance analysis are shown in Table I. We consider the 100 mobile nodes and are distributed in the wireless communication region of 1500m* 1500 m. Each node consists of the 100 joules of energy and can hold the 10 packets in its buffer and the packet size consider for communication is 512 Kbytes with delay-sensitive data. The performance evaluation metrics are packet delivery, delay, and load balance efficiency and network lifetime. The performance is compared with recent existing mechanisms such as Buffer based load balancing (BDLB) [1] and energy delay-based load balancing method (EDLB)[2].

The results are shown in Fig. 4, 5, 6, and 7, and they clearly indicate that the performance of the network is enhanced by the proposed routing protocol.

Fig. 4 shows the packet delivery fraction performance in terms of increased data rates, it is clearly indicating that the proposed routing protocol deliver all the packets to the destination, as it is free from the packet drop due to either lack of energy or buffer overflow.

TABLE I. Performance Evaluation Parameters

Parameters used	**values**
Time	1200 s
Nodes	100
Layer	Logical Link
MAC protocol	802.11
Communication	Two-Ray Ground
Network layer	BBLB, EDLB Proposed
Mobility	Random-way point
Queuing Method	Priority
Traffic	CBR
Energy	100J
Network Area	1500m x1500m

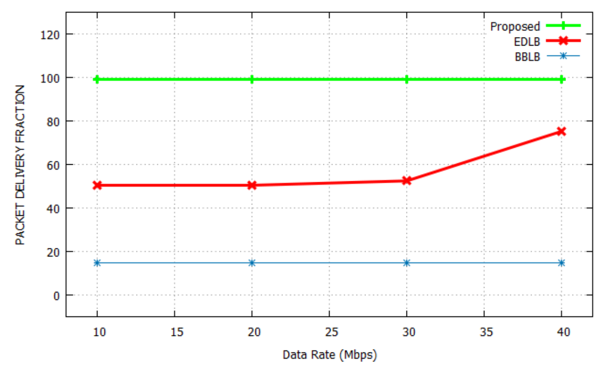

Fig. 4. Packet Delivery Fraction Performance Comparison.

The delay of the network is low in the proposed routing protocol, as it will not consider the nodes whose transmission delay is high, and which is higher than the MAC delay. The delay comparison is shown in Fig. 5.

Fig. 6 shows the energy consumption and packet delivery fraction comparison, it is clearly mentioned that the packet delivery of the proposed routing mechanism is high with less energy consumption.

The efficiency of Load balance is calculated as the ratio of the packets balanced due to the selection of non-congested efficient node to a total number of packets. Packet delivery of a proposed routing protocol extended due to load balancing at node buffer is constructed at the proposed routing protocol, and it is shown in Fig. 7.

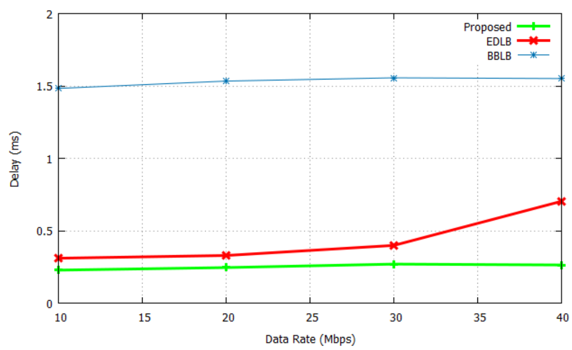

Fig. 5. End to End Delay Performance Comparison.

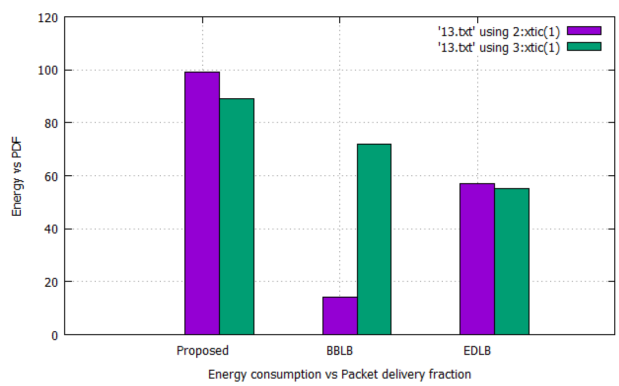

Fig. 6. Comparison between Energy Consumption vs Packet Delivery Fraction.

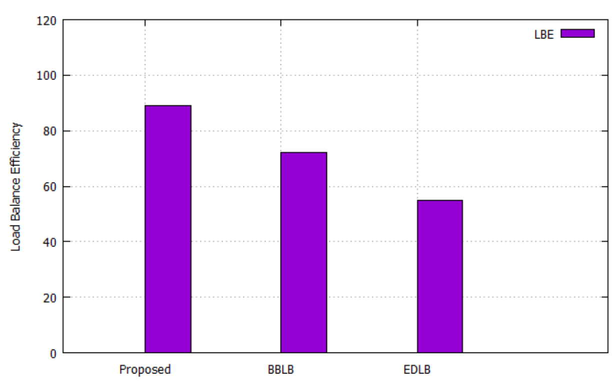

Fig. 7. Comparison of Load Balancing Efficiency.

VII. Conclusion

Wireless mesh network communication gains user attractions due to its deployment flexibility. The main challenging task in the WMN is the provision of Quality of Service due to unbalanced traffic. The recent advancement in wireless technology has fueled the user's attraction towards the delay-sensitive services, which in turn additional impact on WMN to provide QoS. The paper's aim is to provide the QoS in the WMN by load balancing. In literature, various mechanisms have been designed to adder the issue, but they fail to achieve the optimal solution in terms of throughput and energy efficiency. Thus, the work designed the energy-efficient load balancing routing metric to address the limitations of existing conventional methods. Load balancing is accomplished by the selection of non-congested nodes, and energy efficiency is attained by the selection of the greatest packet processing nodes for communication. Performance results show that the proposed routing protocols outperformed in comparison with existing Buffer based load balancing, and energy delay-based load balancing routing protocols. The future work will focus to find the packets drop in the network due to malicious reasons, and further to design the routing protocol to avoid the packets drops due to malicious reasons as well as packets drop due to constrained resources issue.

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Vertical Handover Algorithm for Telemedicine Application in 5G Heterogeneous Wireless Networks

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***Abstract*—In this fast-paced technology era, the advancement of telecommunication systems has made many advanced technologies possible. With the help of the 5G technology, more technologies will become a reality and telemedicine is one of them. Numerous studies have shown that the fatal rate of ischemic heart disease cases can be reduced by sending the real-time patient health data from an ambulance to the medical centre so that healthcare professionals can make early preparation and give immediate treatment in the golden hour. 5G technology offers a high data rate and low latency. However, the coverage of 5G is small compared to 4G. It will induce a high number of unnecessary handovers when an ambulance traverses the 5G networks at high speed and lead to degradation of services quality. Therefore, a fast and accurate vertical handover decision-making algorithm is needed to minimize unnecessary handover in high-speed scenarios. This paper proposes a handover algorithm that integrates the Travelling Time Estimation, Fuzzy Analytic Hierarchy Process (FAHP) and Technique for order of preference by similarity to ideal solution (TOPSIS) algorithms to reduce unnecessary handover in 5G heterogeneous networks. The simulation results show that the proposed algorithm has successfully reduced up to 80.3% of handovers compared to FAHP-TOPSIS based handover algorithm in the high-speed scenario. The proposed handover algorithm can improve the quality of telemedicine services in high-speed scenarios.**

Keywords—Mobile terminal; vertical handover; heterogeneous networks; unnecessary handover; telemedicine; TOPSIS

I. Introduction

In this fast-paced technology era, the advancement of telecommunication systems has made many advanced technologies possible. With the help of the Fifth Generation (5G) telecommunication technology, more technologies will become a reality and telemedicine is one of them. The quality of telemedicine services is greatly affected by network quality. The higher the bandwidth, the better the quality of service. However, the bandwidth requirement is depending on the types of telemedicine service. For example, the transmission of medical video or images requires higher bandwidth than vital signs.

Apart from the network quality, the network coverage issue needs to be taken into consideration. A telemedicine system that relies on a single network cannot guarantee that the user always connects to the healthcare centre. A telemedicine system that can connect to heterogeneous wireless networks is required to allow the users to connect to the network anywhere [1].

Studies have proved that the fatality rate of ischemic heart disease cases is noticeably reduced with the help of telemedicine [2]. One of the methods could be to send real-time patient health data from an ambulance to the medical centre so that healthcare professionals can prepare early, such as setting up the operating theatre and give immediate treatment once the patient arrived at emergency centre. This method is possible with the help of 5G network because it offers a high data rate and low latency [3][4]. But the 5G network coverage is small compared to 4G. It will induce a high number of handovers when the ambulance traverses 5G networks at high speed. A high number of handovers or unnecessary handovers will cause packet loss and data corruption, leading to degradation in telemedicine services.

The integrity of real-time health data transmitted from a high-speed ambulance to the medical centre is crucial to prevent misinterpretation and misdiagnosis by healthcare professionals. Therefore, an effective and precise handover decision making algorithm for telemedicine application in 5G heterogeneous networks is proposed to minimize the unnecessary handover when the ambulance is traversing 5G heterogeneous wireless networks at high speed. The proposed algorithm should also select the network that fulfils the service requirements while maintaining user satisfaction at the highest level.

The rest of the paper is organized as follow. Section II reviews the existing handover algorithms in heterogeneous networks. Sections III and IV discuss the methodology of the proposed handover algorithm and experiment setup, respectively. The performance of the proposed handover algorithm is discussed in Section V. Section VI concludes the paper.

II. Related Work

Vertical handover allows a mobile terminal (MT) to switch from one network to another without losing the connection. It consists of three phases which are handover initiation, decision, and execution [5]. The handover initiation utilizes the Media Independent Handover Function to discover and retrieve available network information [6]. The handover decision selects the most suitable network based on the network information. The executive phase establishes the connection with the targeted network and releases the serving network [7].

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A handover decision scheme proposed by [8] employed the change rate of the Received Signal Strength (RSS) to predict the travelling distance in a wireless local area network (WLAN) coverage area. MT triggers handover to the network candidates that estimated travelling time is greater than the predefined time threshold. The algorithm has successfully reduced the unnecessary handover rate. However, the handover delay is high because two RSS points within WLAN coverage are needed for the travelling time estimation process. Author in [9] proposed a handover algorithm that combines the travelling distance prediction technique with the bandwidth based handover algorithm. The bandwidth based handover algorithm is less complicated compared to the multi-criteria and intelligence-based handover schemes. It simplifies the handover process and reduces the handover delay. The advantage of applying the travelling time estimation technique is that it reduces the probability of unnecessary handovers when MT traverses the small cell networks at high speed.

An adaptive network selection mechanism for telemedicine systems is proposed by [10]. This algorithm finds the best wireless network based on the user's health condition and service requirements. Similarly, authors in [11] presented a user-centric based handover algorithm for telecardiology applications. This algorithm considers the type of telecardiology services, contextual data such as MT velocity and patient health conditions. User satisfaction has greatly improved by reducing handover failures and selecting the low-cost network while maintaining the service quality. However, this work excluded the small cell network from high-speed environment.

Authors in [11,12] proposed multi-attribute decision making (MADM) based handover algorithms. These schemes show the best use of the channel to efficiently transmit the biosignal by offloading the procedure between Wi-Fi and Long-Term Evolution (LTE). The RSS and signal-to-noise ratio (SNR) values were measured and used to compare with their threshold values. The algorithms reduced the unnecessary handover and provided constant data transmission. The telemedicine-based handover decision making (THODM) algorithm presented by [14] selects the best network based on the MT velocity, user setting, and predefined database. This algorithm has successfully reduced the unnecessary handover rate and optimized the usage of small cell networks in a high-speed environment. However, it did not take QoS parameters into consideration.

Author in [1] presented an Improved-TOPSIS based algorithm for telemedicine application. TOPSIS approach is used because of its multi-attribute decision analysis method, which simultaneously estimates both the best and worst alternatives. The proposed algorithm maximized user satisfaction by selecting the network based on user preference. An intelligent based MADM handover algorithm has been used to improve the handover performance. Authors in [15] proposed MADM handover algorithm that integrated FAHP with TOPSIS and VIKOR algorithm. FAHP was used to determine the weights of each criterion, while FAHP and VIKOR were used to find the best network to initiate handover. The limitation of the FAHP-TOPSIS algorithm is that it will induce a high number of unnecessary handovers at the high-speed scenario. Furthermore, authors in [16] presented a neural network based MADM handover algorithm. Authors in [17] presented a Genetic algorithm (GA) based MADM handover algorithm. Authors in [18] proposed an algorithm using FAHP weighting based on user preference and the TOPSIS method to rank the network candidates. The algorithm is able to lower the total number of handovers and maintain the service quality. However, the authors only considered MT moving at low speed. The number of handovers and unnecessary handovers might increase when MT moves at high speed.

The intelligence based MADM based handover decision making system is suitable for telemedicine application because it can accurately select the best network. Moreover, the more handover criteria taken into account, the better the handover performance. However, most existing MADM based handover algorithms did not consider handover performance at high-speed scenarios. In this paper, we proposed a new handover decision making algorithm that integrates the travelling time estimation technique with the intelligence based MADM handover algorithm.

III. Methodology

The proposed handover scheme integrates the Travelling Time Estimation, FAHP and TOPSIS algorithms. The Travelling Time Estimation algorithm is used to predict the travelling time in the small cell networks. FAHP algorithm is selected to determine the handover criteria weights that will be used in the TOPSIS algorithm. TOPSIS ranks all the network candidates and selects the best network to initiate handover.

A. *Travelling Time Estimation*

The Travelling Time Estimation algorithm prevents unnecessary handover to small cell networks by excluding the network candidates that have an estimated travelling or network connection time less than the predefined threshold time. This algorithm only applies in small cell networks such as WLAN and 5G. The threshold time is set at two seconds [13, 19]. The scenario of MT traversing the small cell network is illustrated in Fig. 1. The travelling time in the small cell network, *T*, can be predicted using (1) [14].

$$T = \frac{R^2 - r^2 - d^2}{dv} \tag{1}$$

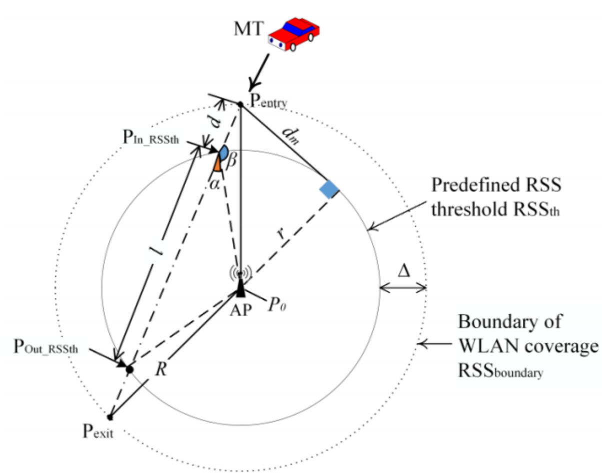

Fig. 1. MT Trajectory within Small Cell Network [14].

where R denotes the radius of the access point (AP), r is the radius of AP and Predefined RSS threshold. d represents MT travelling distance between the P_{in_RSSth} and P_{entry}. v is the velocity of the MT, and it can be obtained through the vehicle/ambulance's speedometer. The R and r values can be calculated by using the Log-distance path loss model as described in [14].

B. Fuzzy-Analytic Hierarchy Process

The first step of the FAHP is to create a decision matrix regarding its parameters for each access network [15] as illustrated as in (2).

$$P = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccccc} C_1 & C_2 & C_3 \cdots & \cdots & C_n \end{array} \\ \left|\begin{array}{cccccc} x_{11} & x_{12} & x_{13} \cdots & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} \cdots & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & & \vdots \\ \vdots & \vdots & \vdots & & \vdots \\ x_{m1} & x_{m2} & x_{m3} \cdots & \cdots & x_{mn} \end{array}\right| \end{array} \quad (2)$$

where A_i (i from 1 to m) represents the network candidate, C_j (j from 1 to n) denotes the criteria used for handover and x_{ij} represents the value of the network i with respect to the criterion j.

Secondly, data in the matrix P need to be normalized and construct the normalize data into normalized decision matrix r given as

$$r = \begin{bmatrix} r_{11} & \cdots & r_{1j} & \cdots & r_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{i1} & \cdots & r_{ij} & \cdots & r_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{m1} & \cdots & r_{mj} & \cdots & r_{mn} \end{bmatrix} \quad (3)$$

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \; i = 1,2, \ldots m, j = 1,2, \ldots n \quad (4)$$

where r_{ij} is a normalized value of element x_{ij}.

After obtaining the normalized matrix, the weight value for each handover criteria can be calculated using FAHP. A pair-wise comparison matrix can be determined as follows:

$$\tilde{A} = (\widetilde{a_{ij}})_{n\times n} = \begin{bmatrix} (1,1,1) & (l_{12}m_{12}u_{12}) \cdots & (l_{1n}m_{1n}u_{1n}) \\ (l_{21}m_{21}u_{21}) & (1,1,1) \ldots & (l_{2n}m_{2n}u_{2n}) \\ (l_{n1}m_{n1}u_{n1}) & (l_{n2}m_{n2}u_{n2}) \ldots & (1,1,1) \end{bmatrix} \quad (5)$$

where l, m, u denotes the lower bound value, mid-value and upper bound of the triangular fuzzy number based on Satty's AHP scale table as shown in Table I.

TABLE I. SATTY'S AHP SCALE

Linguistic terms	Fuzzy triangular numbers	Reciprocal fuzzy triangular numbers
Equally important	(1,1,1)	(1,1,1)
Moderately important	(2,3,4)	(1/4,1/3,1/2)
Strongly important	(4,5,6)	(1/6,1/5,1/4)
Very strongly important	(6,7,8)	(1/8,1/7,1/6)
Absolutely important	(7,9,9)	(1/9,1/9,1/7)

Next is to calculate the Fuzzy geometric mean value $\widetilde{r_1}$ given as.

$$\widetilde{r_1} = (l_1 m_1 u_1) \otimes (l_2 m_2 u_2)^{\frac{1}{n}} \quad (6)$$

where n represents the number of criteria. After obtaining the Fuzzy geometric mean value, the fuzzy weight $\widetilde{w_1}$ can be obtained as follows:

$$\widetilde{w_1} = \widetilde{r_1} \otimes (\widetilde{r_1} \oplus \widetilde{r_2} \oplus \ldots \oplus \widetilde{r_n})^{-1} \quad (7)$$

Lastly, the defuzzification process is applied to fuzzy weight to obtain the value of the weights w_i, given as.

$$w_i = \left(\frac{l+m+u}{3}\right) \quad (8)$$

The normalized weights of each criterion can be obtained by.

$$Normalized\ Weight = \frac{Weights}{Sum\ of\ Weights} \quad (9)$$

C. TOPSIS

The TOPSIS approach ranks the network candidates and finds the best network based on the user preference and the telemedicine service requirements. After the user rates every criterion based on Table I, weights can be obtained. In the defuzzification process, the normalized decision matrix $\tilde{P}$ will be multiplied with the fuzzy weight array w_i to obtain the weighted normalized decision matrix $\tilde{X}$.

$$\tilde{X} = \tilde{P} * w_i = \begin{bmatrix} w_1 x_{11} & \cdots & w_j x_{1j} & \cdots & w_n x_{1n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1 x_{i1} & \cdots & w_j x_{ij} & \cdots & w_n x_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ w_1 x_{m1} & \cdots & w_j x_{mj} & \cdots & w_n x_{mn} \end{bmatrix} \quad (10)$$

Based on the normalized decision matrix $\tilde{X}$, the fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS) can be obtained as follows:

$$\tilde{I}^{+} = (X_1^{+}, \ldots, X_j^{+}, \ldots, X_n^{+}) \quad (11)$$

$$\tilde{I}^{-} = (X_1^{-}, \ldots, X_j^{-}, \ldots, X_n^{-}) \quad (12)$$

where X_j^{+} denotes the $max_i X_{ij}$ and X_j^{-} is the $min_i X_{ij}$.

Then calculate the distances to fuzzy positive and negative ideal solutions, as expressed by (13 and (14), respectively.

$$\tilde{d}_i^{+} = \sqrt{\sum_{j=1}^{n} (\tilde{X}_{ij} - \tilde{I}_j^{+})^2} \quad (13)$$

$$\tilde{d}_i^{-} = \sqrt{\sum_{j=1}^{n} (\tilde{X}_{ij} - \tilde{I}_j^{-})^2} \quad (14)$$

where $\widetilde{d_i^{+}}$ represents the distance to the FPIS from alternative i and $\widetilde{d_i^{-}}$ is the distance to the FNIS from alternative i.

Finally, the computation of the fuzzy relative closeness for each alternative is applied. Let $\widetilde{C_i}$ represents the fuzzy relative closeness coefficient for alternative i. It denotes the degree of proximity to the positive ideal solution. If the computed $\widetilde{C_i}$ is nearly 1, it infers that alternative i approaches the positive ideal solution. It might be the best one among other alternatives. On the other hand, if $\widetilde{C_i}$ is far less than 1, alternative i will not be the best one. Fuzzy relative closeness coefficient can be obtained by.

$$\widetilde{C_i} = \frac{\widetilde{d_i^-}}{\widetilde{d_i^-}+\widetilde{d_i^+}} \; (i = 1,2,\ldots,n) \tag{15}$$

The $\widetilde{C_i}$ values are averaged and are ranked all network candidates in descending order. The highest value of $\widetilde{C_i}$ will be the most appropriate network to handover. The flowchart of the proposed handover algorithm is shown in Fig. 2.

The proposed handover algorithm starts with monitoring the quality-of-service (QoS) of the serving network, user preference and services requirements such as video, voice, electrocardiogram (ECG) and vital signs. If the QoS of the serving network meets the services requirements and user preference, MT will stay connected to the serving network and continue monitoring the network QoS. Otherwise, the proposed algorithm will scan for alternate networks to search for a better network to maintain the quality of services. The proposed algorithm will first check if any small cell network is detected. If any small cell network is detected, the travelling time estimation algorithm will be used to predict the travelling time within the network. Only the network candidates whose estimated travelling time are greater than the threshold value will proceed to the next step, FAHP and TOPSIS algorithms, for network quality evaluation. Otherwise, the algorithm will reject it and scan for alternate networks. If a large cell network such as an LTE network is detected, the proposed algorithm will directly proceed to the FAHP and TOPSIS algorithm because large cell networks could support the MT moving at high speed.

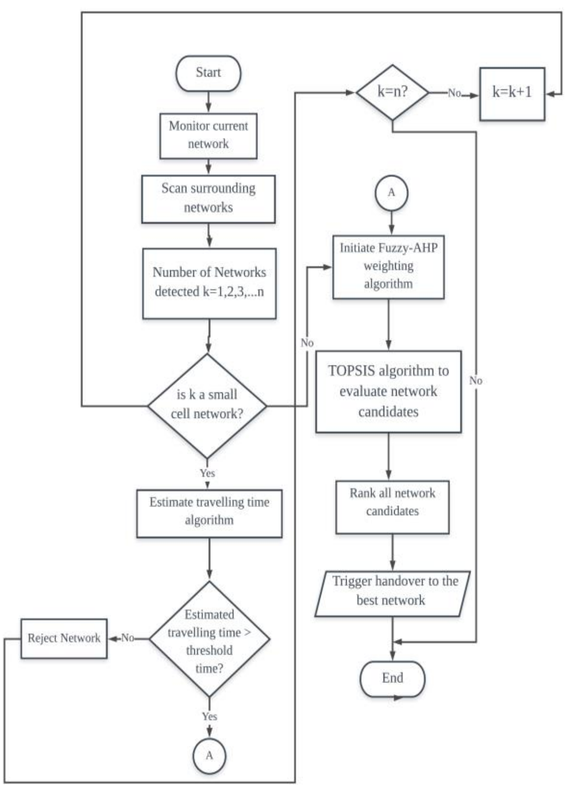

Fig. 2. Proposed Vertical Handover Algorithm.

The FAHP algorithm calculates the weight for each handover criterion used in TOPSIS based on the user preference rating. For example, users can choose and rate the criteria using the linguistic term for the low-cost network such as WLAN. After obtaining the weights, the TOPSIS algorithm will evaluate all the network candidates and form a ranking system to determine which network is the best. The best network candidate will be chosen for handover.

IV. Experiment Setup

A 5G heterogeneous wireless networks environment that consists of WLAN, LTE, and 5G, as shown in Fig. 3, is created using MATLAB to evaluate the performance of the proposed handover scheme. The network coverage diameter for WLAN, 5G and LTE is 120 m, 300 m, and 16 km, respectively. The LTE network covers all 5G and WLAN cells. The handover parameters considered in this work are cost, delay, data rate, and packet loss rate (PLR), as tabulated in Table III.

Assuming that the MT (ambulance) moves from point A to destination B. It traverses the 5G heterogeneous networks at high speed and transmitting real-time ECG, audio, vital, and voice to the healthcare centre. The total bandwidth required for the telemedicine service is 829 Kbps [20], as shown in Table II. The ambulance was initially connected to the LTE network. It traverses the network 5G1, followed by WLAN 1, 5G 2, WLAN 2, 5G 3, 5G 4, WLAN 3 and WLAN 4.The proposed handover algorithm selects the most suitable network based on service requirements and user preference.

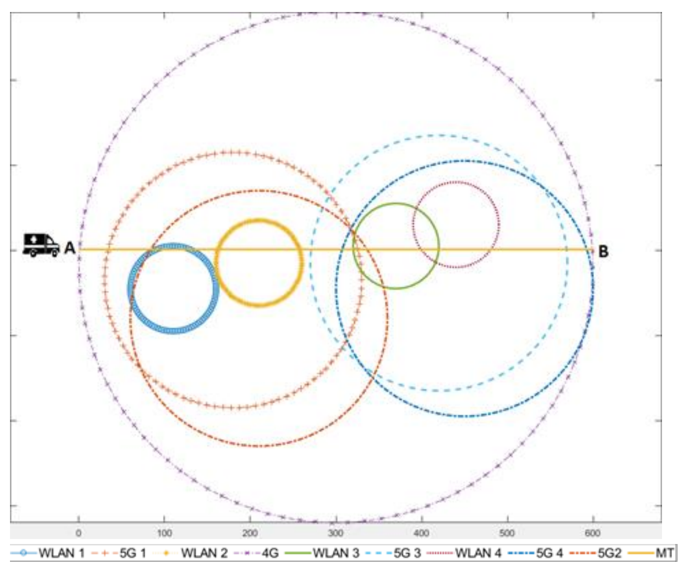

Fig. 3. Heterogeneous Wireless Networks Environment.

TABLE II. Bandwidth Requirement for Telemedicine [20]

Services	Bandwidth
Video	640 – 5000 kbps
Audio	32 – 256 kbps
ECG	24 kbps/12leads
Vital Signs	2 – 5 kbps

TABLE III. SIMULATION PARAMETERS [16, 20, 21].

Parameters	LTE	5G	WLAN
Carrier frequency	1.9 GHz	26 GHz	2.4 GHz
Coverage (radius)	16 km	300 m	120 m
Data rate	20 Mbps	1 Gbps	50 Mbps
Cost	8	60	1
Delay (ms)	15	1	7
PLR	0.001	0.0001	0.002

V. RESULT AND DISCUSSION

In order to obtain weights based on user preference, the value of the pair-wise comparison matrix is set by the user based on Satty's AHP scale shown in Table IV. Assuming the user wants to save cost and set the cost parameter extremely preferred over all other criteria. While comparing with the same criteria, it will be equally important and cannot be changed by the user.

With the data collected from Table IV, the mean and sum of Fuzzy Geometric values can be obtained using (6), and the results are tabulated in Table V. These values are used for calculating the fuzzy weight. The fuzzy weight can be concluded into three values that are l, m, u to form a fuzzy triangular number which stands for lower bound value, mid-value and upper bound, respectively, as shown in Table VI. The next step is the defuzzification process to get the normalized weight value for each criterion. Defuzzification is defined as changing the fuzzy weight number into a single crisp weight value by applying (8). Normalized weights for each criterion are shown in Table VII. The cost has the highest weightage compared to other parameters. As a result, the handover algorithm is biased to low cost networks such as WLAN because it has the lowest cost compared to LTE and 5G.

The handover performed by the proposed handover algorithm with MT moving at 60 km/h is illustrated in Fig. 4, while Fig. 5 shows the handover performance of FAHP-TOPSIS based handover algorithm [15]. It can be seen in Fig. 4, the proposed handover algorithm did not handover to WLAN 1 because the travelling time of WLAN 1 is less than 2 seconds, while the FAHP-TOPSIS based handover algorithm handovers to any WLANs detected by MT (as shown in Fig. 5). Additionally, the algorithm handovers to LTE instead of 5G is because the 5G cost is higher than LTE. Therefore, the proposed algorithm handover to LTE right after disconnecting from WLAN.

The performance of the proposed handover algorithm at the speed of 120 km/h can be seen in Fig. 6. It did not handover to WLAN 1 and WLAN 2 because the travelling time within the WLAN 1 and WLAN 2 was less than 2 seconds when the MT travelled at the speed of 120 km/h. The travelling time becomes shorter due to MT traverses the network at a higher speed. The proposed algorithm only handovers to WLAN 5 and WLAN 7. However, the FAHP-TOPSIS based handover algorithm handovers to WLAN whenever it is available and ping pong effect is higher than the proposed algorithm, as shown in Fig. 7. The total number of handovers and unnecessary handovers of the proposed handover algorithm is significantly reduced compared with FAHP-TOPSIS based handover algorithm, as shown in Table VIII.

TABLE IV. MEAN AND SUM OF FUZZY GEOMETRIC VALUE

	FUZZY GEOMETRIC MEAN VALUE ($\tilde{r}_i$)		
	5.061	6.240	6.240
	0.693	0.693	1.504
	0.577	0.693	1.252
	0.480	0.693	1.043
	0.399	0.693	0.868
	0.333	0.693	0.723
Sum of geometric value	**7.543**	**9.705**	**11.630**
r^{-1}	**0.086**	**0.103**	**0.133**

TABLE V. PAIR-WISE COMPARISON MATRIX FOR CRITERIA WEIGHTS

	COST			**DR**			**DELAY**			**PLR**			**BER**			**SINR**		
COST	1	1	1	7	9	9	7	9	9	7	9	9	7	9	9	7	9	9
DR	1/9	1/9	1/7	1	1	1	1	1	3	1	1	3	1	1	3	1	1	3
DELAY	1/9	1/9	1/7	1/3	1	1	1	1	1	1	1	3	1	1	3	1	1	3
PLR	1/9	1/9	1/7	1/3	1	1	1/3	1	1	1	1	1	1	1	3	1	1	3
BER	1/9	1/9	1/7	1/3	1	1	1/3	1	1	1/3	1	1	1	1	1	1	1	3
SINR	1/9	1/9	1/7	1/3	1	1	1/3	1	1	1/3	1	1	1/3	1	1	1	1	1

TABLE VI. FUZZY WEIGHT VALUES

	Fuzzy Weight, W_i		
	Lower Bound	Mid-Value	Upper Bound
COST	0.435	0.643	0.83
DR	0.060	0.071	0.2
DELAY	0.050	0.071	0.167
PLR	0.041	0.071	0.139
BER	0.034	0.071	0.115
SINR	0.029	0.071	0.096

TABLE VII. WEIGHT OF EACH CRITERION

	Weights	Normalized Weight
COST	0.636	0.598
DR	0.11	0.103
DELAY	0.096	0.09
PLR	0.084	0.079
BER	0.073	0.069
SINR	0.065	0.061
TOTAL	**1.064**	**1**

TABLE VIII. PERFORMANCE OF THE PROPOSED HANDOVER ALGORITHM AND FAHP-TOPSIS BASED HANDOVER ALGORITHM FOR SINGLE ITERATION

MT velocity	Total Handover		Unnecessary Handover	
	FAHP-TOPSIS	Proposed	FAHP-TOPSIS	Proposed
60 km/h	20	5	15	0
120 km/h	21	3	18	0

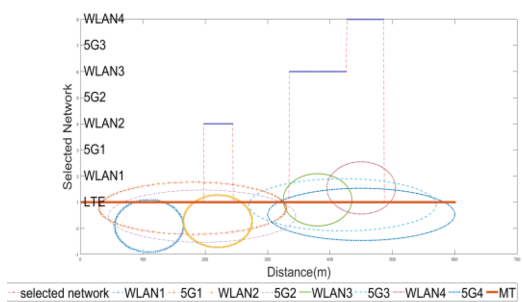

Fig. 4. Handover Performed by the Proposed Handover Algorithm at the Speed of 60 km/h.

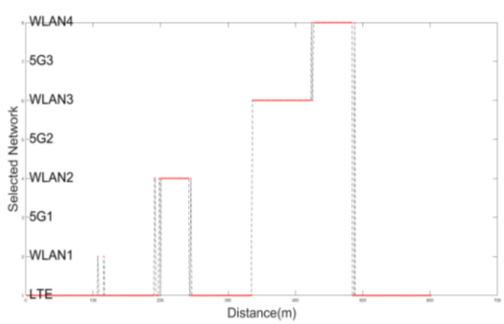

Fig. 5. Handover Performed by FAHP-TOPSIS based Handover Algorithm at the Speed of 60 km/h.

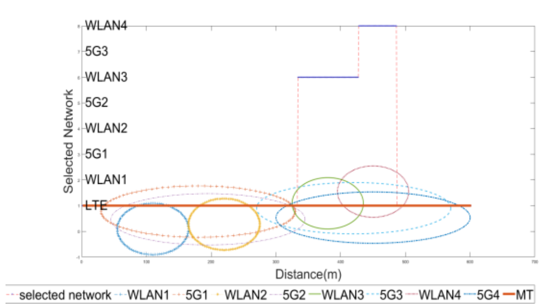

Fig. 6. Handover Performed by the Proposed Handover Algorithm at the Speed of 120 km/h.

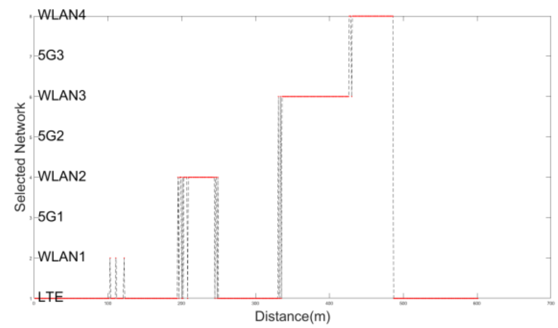

Fig. 7. Handover Performed by FAHP-TOPSIS based Handover Algorithm at the Speed of 120 km/h.

The proposed handover algorithm has been simulated for 500 iterations to obtain more accurate results. The total number of handovers performed by the proposed handover algorithm and FAHP-TOPSIS based handover algorithm is 2514 and 12776, respectively. The proposed algorithm has reduced the number of handovers up to 80.3% compared to FAHP-TOPSIS based handover algorithm [15]. The FAHP-TOPSIS based handover algorithm [15] induces a high number of unnecessary handovers when the MT travels at high speed. With the implementation of the prediction technique, the proposed handover algorithm has significantly reduced the number of unnecessary handovers in the high-speed scenario. Additionally, the ping-pong effect is also greatly reduced in the proposed handover algorithm.

VI. CONCLUSION

This paper proposed a new handover algorithm that integrates travelling time estimation, FAHP and TOPSIS algorithms. The proposed handover algorithm has improved the handover performance in the high-speed scenario. The number of unnecessary handovers has been greatly reduced. Additionally, the strength of the proposed handover algorithm is that it uses the fuzzy set theory to eliminate uncertainty and vagueness throughout the pairwise comparison process and travelling time prediction algorithm to minimize unnecessary handover to small cell networks. Furthermore, the TOPSIS approach ranks and finds the best network candidate based on user preference and telemedicine service requirements. The proposed handover algorithm has significantly minimized the number of unnecessary handovers and improved user satisfaction by selecting the lower cost network while maintaining the quality of telemedicine service.

In this work, we assumed the speed of MT is constant while traversing the network. It may cause an increase in the probability of unnecessary handover if MT is accelerating because MT will leave the network coverage earlier than the estimated time. The performance of the proposed handover decision making algorithm can be further improved if the algorithm adapts to change in MT velocity.

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Analysis of Electroencephalography Signals using Particle Swarm Optimization

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***Abstract*—Brain computer interface devices monitor the brain signals and convert them into control commands in an attempt to imitate certain human cognitive functions. Numerous studies and applications have developed, because of the researchers' interest in systems in recent years. The capacity to categorize electroencephalograms is essential for building effective brain-computer interfaces. In this paper, three experiments were performed in order to categorize the brain signals with the goal of improving a model for EEG data analysis. An investigation is carried out to detect the characteristics derived from interactions across channels that may be more accurate than features that could be taken from individuals. Many machine learning techniques were applied such as; K-Nearest Neighbors, Long Short-Term memory and Decision Tree in this paper in order to detect and analyze the EEG signals from three different datasets to determine the best accuracy results using the particle swarm optimization algorithm that obviously minimized the dimension of the feature vector and improved the accuracy results.**

Keywords*—Electroencephalographic; k-nearest neighbors; long short-term memory; epileptic seizure recognition; decision tree

I. Introduction

Brain-Computer Interface (BCI) it is a fast-expanding scientific issue that is attracting the attention of experts from all around the world which utilizing brain activity to transmit orders to an electrical device, BCI developed a new communication channel [1]. Neurologically impaired individuals control electronic gadgets such as dementia, epilepsy and sleeping problems [2]. BCI systems are primarily intended for use by the blind. As defined by the Brain-Computer Interface, Ideally, this should be capable of recognizing human objectives and communicating them to the computer, in which appropriate measures are taken. As a result, there are two types of BCIs: invasive and non-invasive, accordance to the method through which the BCI system measures brain activity. As an example, if the measuring sensors are located in the brain or skull, consider that: The BCI system is characterized as an invasive BCI system. However, if the measuring sensors are implanted on the scalp, but not on the skull, then, it is possible that the findings will be different. The BCI system, for example, is categorized as non-invasive BCI [2] Using non-invasive BCI systems versus invasive systems has the advantage of reducing or eliminating health risks the ethical issues that arise from them, etc. Ordinary personnel are not likely to benefit from invasive approaches [1, 3].

Brain signals, signal processing, signal acquisition, application execution, and output feedback are typical components of a BCI system. After being detected and monitored by signal acquisition, pre-processing stages filter electrical brain signals. Feature extraction and classification are among the operations performed in the signal processing phase, Sends necessary commands to suitable devices. while the functioning of these devices, the user may receive some form of feedback (s). The block diagram of a BCI system is shown in "Fig. 1" [3].

The following is a breakdown of the paper: Section II shows the necessary machine learning baseline knowledge, Section III provides required Electroencephalography signals background, Section IV provides detailed description of the used datasets, Section V shows the proposed model, Section VI discuss the evaluation results, lastly conclusion is providing in Section VII.

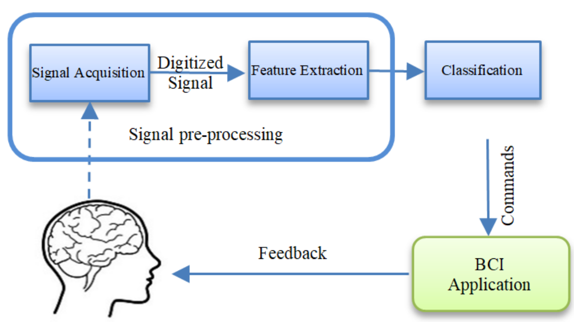

Fig. 1. Block Diagram of a BCI System.

II. Background

In order to do the given task, the BCI device collects brain waves and transfers these waves to the computer system for analysis and processing. It is therefore possible to represent a concept or operate some items using the waves that have been delivered.

A. BCI Functions

Using Brain Computer Interface apps, users may either be informed of their current condition or provide their own opinions about it. To do the stated task, the BCI system records brainwaves and sends them through computer to a computer system. It is so possible to express an idea or operate an item using the transmitted waves. Brain Computer Interface apps work by either sensing the user's circumstances or by letting the user to express his/her feelings and ideas [4].

B. Control and Communication

Human brain-computer interface (BCI) systems establish a link with the outside world; traditional information transfer mechanisms are no longer needed. Signals from human brains are controlled, as are their silent thoughts. This allows them to communicate and record thoughts and ideas utilizing a variety of various techniques, such as in semantic categorization [5], spelling applications [6], or silent speech communication [7]. Hands-free applications may be enabled by BCIs, machine mind control for human ease and comfort. To carry out a set of orders, they just require the integration of brain impulses, and no physical movement is necessary [8, 9, 3]. Assistance robots using BCI technology can support individuals with disabilities in their daily and professional life, allowing them to be more involved in community building activities [10].

C. User State Monitoring

BCI applications were aimed towards handicapped users who had communication or mobility problems. Their intention was to supply those users with an alternate communication bridge. Then, later, BCI impacts the universe of healthy individuals as well. It functions as a physiological measurement technique, retrieving and utilizing data regarding an individual's emotional, cognitive, or effectiveness condition. In what is known as passive BCI, the goal of brain signal usage has been expanded beyond commanding an item or providing a substitute for certain functions [11].

III. Electroencephalography (EEG)

When synaptic stimulation of neurons dendrites is measured with electroencephalography (EEG), electric brain activity is monitored, the properties of secondary currents, and it is very sensitive to them. EEG recording system comprises of electrodes, A/D converter, amplifiers, and a recording device. Analogue signals are amplified by the amplifiers before being sent to the A/D converter, which allows the information to be digitized more effectively. Finally, the data is recorded and displayed by the capturing device, which may be a computer or something similar.

EEG signals are recorded using the electrodes. The International 10–20 system is frequently used for electrodes positioned on the scalp; tThe American Electroencephalographic Society has standardized this method. To determine the electrode placement in the 10–20 system, two reference locations in the scalp are used, the nasion is one of these points of reference, it is positioned at the same level as the eyes on the top of the nose. The inion is the second point of reference, situated in the bony hump at the skull's base. The skull is divided into two halves by the transverse and median planes. The positions of the electrodes are established by designating those sectors at 10% and 20% intervals. Each letter refers to a different area of the brain. Which that The earlobe is represented by the letter A, the central region is represented by the letter C, the nasopharyngeal is represented by Pg, the parietal is represented by letter P, the frontal is represented by letter F, the frontal polar is represented by Fp, and finally the occipital area is represented by letter O [8].

Due to the huge quantity of information collected from each electrode, Continuous EEG data or brain waves might be difficult to analyze. As a field of science, it must be accompanied with a complex collection of terms. Waves, like radio stations, are categorized based on their frequency and, in certain cases, their waveforms. Even though none of these waves are ever generated alone, an individual's state of awareness can cause one frequency range to be much more prominent than others.

In this paper, analysis of some cases to the human states will be applied to detect their mental state, and human emotional feelings and to recognize if they have Epileptic seizure or not by using EEG signals.

A. Mental State

The capability Automatic detection of a human's mental state, if they are cognitive or affective, is helpful for a variety of applications across a wide range of disciplines like robotics, medical care, education, neurology, and so forth. The significance of effective human-machine interaction mechanisms grows in direct proportion to the total number of real-world situations in which smart devices are used, autonomous robots included, can be used. Signals of surface brain activity are one way to connect with machines. These signals, known as electroencephalograms or EEGs for short, Electrode’s measure voltage and communicate that information (dry or wet) positioned over a human's scalp. In addition to the standard non-invasive electroencephalography, there is many invasive options that can analyze activities in the brain by implant electrodes directly on the human's skull [11].

B. Emotional Feelings

Independent non-invasive monitoring of emotional states has the potential to be beneficial in a variety of fields, User and device engagement may be enhanced by incorporating human-robot interaction and mental healthcare, Information may be gathered that is not dependent on spoken communication by using augmented reality [12]. Electroencephalography (EEG) technology has become increasingly affordable; brainwave data is becoming more affordable for consumers and researchers alike, self-categorization without the requirement for an expert. In the raw EEG stream, classification is challenging because of the unpredictability and non-stationary nature of brainwave data. As a result, with feature extraction of data inside a window, stationary approaches such as temporal windowing must be incorporated. Many statistics may be generated from such EEG windows, each with a different classification efficacy depending on the aim. To find important statistics and decrease the complexity of the model development process, feature selection must be done, saving both time and computing resources throughout the training and classification procedures [12].

C. Epileptic Seizure Recognition

Epilepsy is a neurological condition marked by unexpected and recurring seizures. Epilepsy can affect awareness, perception, feeling, behavior, and physical movement by causing aberrant electrical activity in the brain. During seizures, patients suffer from some symptoms according to the position of the injured brain area. Fortunately, most epileptic seizures are momentary and seldom life-threatening. In 1981, the International League Against Epilepsy (ILAE) supposed that there are two kinds of seizures comprises: a) Seizures that affect virtually the whole brain which called generalized seizures. B) Seizures that begin in the brain in particular part and persist restricted to that region named as partial (or focal) seizures [13].

IV. Data Sets

For many scientists, the phrase "Machine Learning" is synonymous with "Artificial Intelligence," like the ability to learn which is the primary attribute of an entity termed as intelligence. Learning from the human knowledge in order to develop computer systems, is always the goal behind using the machine learning.

A. EEG Brainwave Dataset: Mental State

The Muse Headband sensor was utilized to collect data. Each of the three states - relaxed, focused, and neutral - was recorded for 60 seconds by four persons (2 males and 2 females). We used a Muse EEG headband with dry electrodes to capture the TP9, AF7, AF8, and TP10 EEG placements. To avoid electromyography signal interference, Nonverbal activities requiring little to no movement were assigned. Blinking, despite interfering with the AF7 and AF8 sensors, was neither encouraged nor discouraged from maintaining its natural nature. This was attributed to the blink rate's dynamic relationship with tasks demanding varying levels of attention [14], As a result, the categorization algorithms would take these signal spike patterns into consideration. Additionally, during any of the exercises, the individuals were not permitted to close their eyes. Three stimuli were created to cover the Muse Headband's three mental states: relaxed, neutral, and focused. The individuals were advised to relax their muscles and rest meditates while listening to low-tempo music and sound effects. A comparable test was performed for a neutral mental state, but with no stimulus at all. This test was performed before to any others to avoid the long-term consequences of a mentally calm or focused state of mind. so, during a "shell game," Under one of the three cups, there was a ball, and participants were instructed to find it, which were then exchanged, and the objective was to figure out which cup hid ball. Future work will consist of implementing a standard experiment for each stage in order to properly compare to comparable studies. As a result, erroneous data is not collected; Muse Headband EEG data was automatically recorded for 60 seconds after the stimulation began. The data was seen to be flowing at a fluctuating frequency between 150 and 270 Hz. BlueMuse [15] was employed in order to connect this device to a computer, and Muselsl [16] for converting MUSE signal into micro voltage, as well as to capture and prepare data for feature extraction. “Fig. 2” presentation of EEG data on a real time basis; The TP9 and TP10 (forehead sensors) may be seen blinking. At each point in the data stream, a UNIX timestamp was recorded. (150-270 Hzdown sampled the data to produce a stream frequency that was constant. The EEG locations may be mapped to the observed voltages on the graph. Data has been down sampled before being subjected to feature extraction. Fast Fourier transforms along a particular axis reduced the sample rate to 200 Hz. Len(x) / num * is used to sample the resampled signal, which starts at the same value as x (spacing of x). This is because the Fourier technique assumes that the signal is periodic. Although the frequency range of the EEG sensor is better, this down-sampling is practical since the main energy is focused in the 20-500Hz region.

B. EEG Brainwave Dataset: Feeling Emotions

However, they may be categorized into good and bad categories [18]. Anguish and optimism for the character's survival in a film are two examples of emotions that occur simultaneously. A positive experience shall be defined as one that does not overlap with other pleasant experiences. According to Lövheim's three-dimensional emotional model, the brain's chemical structure corresponds to generalized positive and negative valence states [19]. Each of the model's vertices is labelled A-H in “Fig. 2”, further detailed in Table I. Positive and negative emotions can be linked to chemical compositions. Moreover, investigations have shown that chemical composition impacts neural oscillation and, thus, electrical brainwave production [20] because emotions are contained in chemical compositions that impact electrical brain activity directly, they may be categorized using statistical features of the brainwaves generated, according to this study.

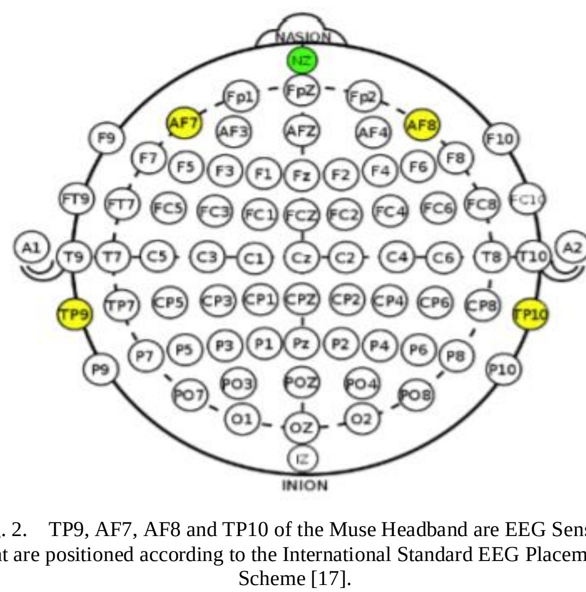

Fig. 2. TP9, AF7, AF8 and TP10 of the Muse Headband are EEG Sensors that are positioned according to the International Standard EEG Placement Scheme [17].

TABLE I. CATEGORIES OF LÖVHEIM AND THEIR VALENCE LABEL OF THE ENCAPSULATED EMOTIONS [19]

Categories of Emotions	Valence/Emotion
A	Shame (-) Humiliation (-)
B	Contempt (-) Disgust (-)
C	Fear (-) Terror (-)
D	Enjoyment (+) Joy (+)
E	Distress (-) Anguish (-)
F	Surprise (-) (Lack of Dopamine)
G	Anger (-) Rage (-)
H	Interest (+) Excitement (+)

C. *Epileptic Seizure Recognition Dataset*

In the research of epilepsy, either humans or animals are employed as subjects. These signals were collected from the Bonn University in Germany, which is public [21]. There are five full datasets (A–E), each of which has 100 single-channel EEG segments. During every segment's 23.6 second length, there are N=4096 sample points collected. The same 128-channel amplifier configuration was used throughout and 12-bit A/D resolution, all EEG signals were captured, there were 17,611 samples per second, and the acquisition system's bandwidth ranged from 0.5 to 85 cycles per second. Visual assessment for artefacts like movement of the muscles, eye blinking, etc. a multi-channel EEG recording was selected for these parts. In a waking state with their eyes open and closed, five healthy participants recorded their external surface EEGs. were used to create Sets A and B, From EEG recordings made with depth electrodes, five individuals were used to create sets C, D and E. Sets A and B were recorded in a regular condition of affairs. Recordings in sets D and C were taken from the epileptogenic zone (inter-ictal period) and the opposite hemisphere's hippocampus formation of the brain, respectively. During seizure activity, Set E was recorded (Ictal). “Fig. 3” displays Five sets A to E of electrodes of EEG data were obtained and analyzed [21].

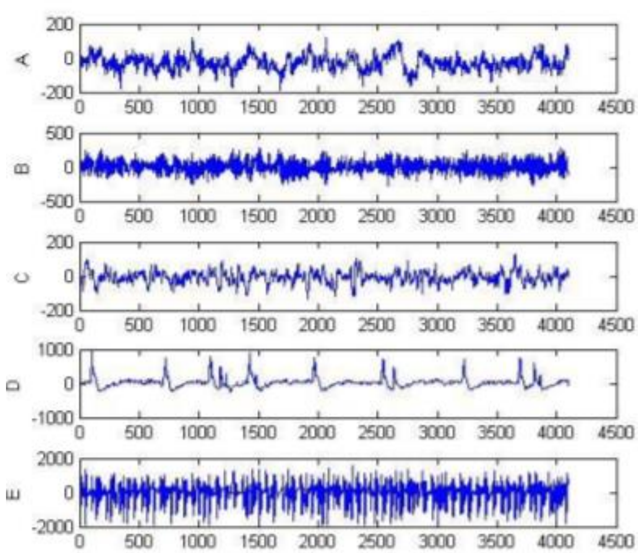

Fig. 3. Recordings Sample of A, B, C, D and E Dataset [21].

V. PROPOSED MODEL

The proposed model in this study was applied on three different datasets of the EEG brainwaves that are mental state, feeling emotions and epileptic seizure recognition datasets (Section IV). As shown in “Fig. 4”, the proposed model in this paper consists of five layers; the first layer include the data input that consists of the three datasets, the second layer is the data acquisition layer in which pre-processing steps are applied after the feature extraction phase, then the feature selection layer took the third place in order to categorize and detect the effect of the Particle Swarm Optimization on the model results before and after applying it with three different classifiers which are; Decision Tree (DT), K-Nearest Neighbor (KNN) and Long Short-Term Memory (LSTM) classifiers in the fourth layer and lastly the fifth layer that checks if the evaluation methods satisfy the objective function it generates the output result, while if not, it returns back to the third layer where the PSO take place again and repeats the same steps until it reaches the optimum output.

A. *Feature Extraction using Particle Swarm Optimization (PSO)*

As a problem of global combinatorial optimization, feature selection decreases the number of features, eliminates noise and superfluous data, and results in classification accuracy acceptable to the user [22]. Machine learning, pattern categorization, and medical data processing, and data mining applications all rely heavily on feature selection. For this reason, a suitable feature selection technique based on the number of characteristics explored for sample classification is essential in order to increase processing speed and prediction accuracy, as well as to prevent incomprehensibility.

B. *Evaluation Methods*

1) K-Nearest neighbor: The KNN classifier is a non-parametric instance-based classification algorithm [23]. Training data are merely stored, and no new information is learned because of this kind of learning [24]. During the training phase, these saved values will be needed. In this technique, the nearest-neighbor estimation method is used. As a result of the distance metric, the new instances are categorized based on similarity as shown in Fig. 5. The Euclidean distance function is the most often utilized. Power spectral density data were classified using KNN. Comparing results with the goal value in mean square error estimates. To assess the efficiency of the KNN classifier, different performance metrics were computed [25].

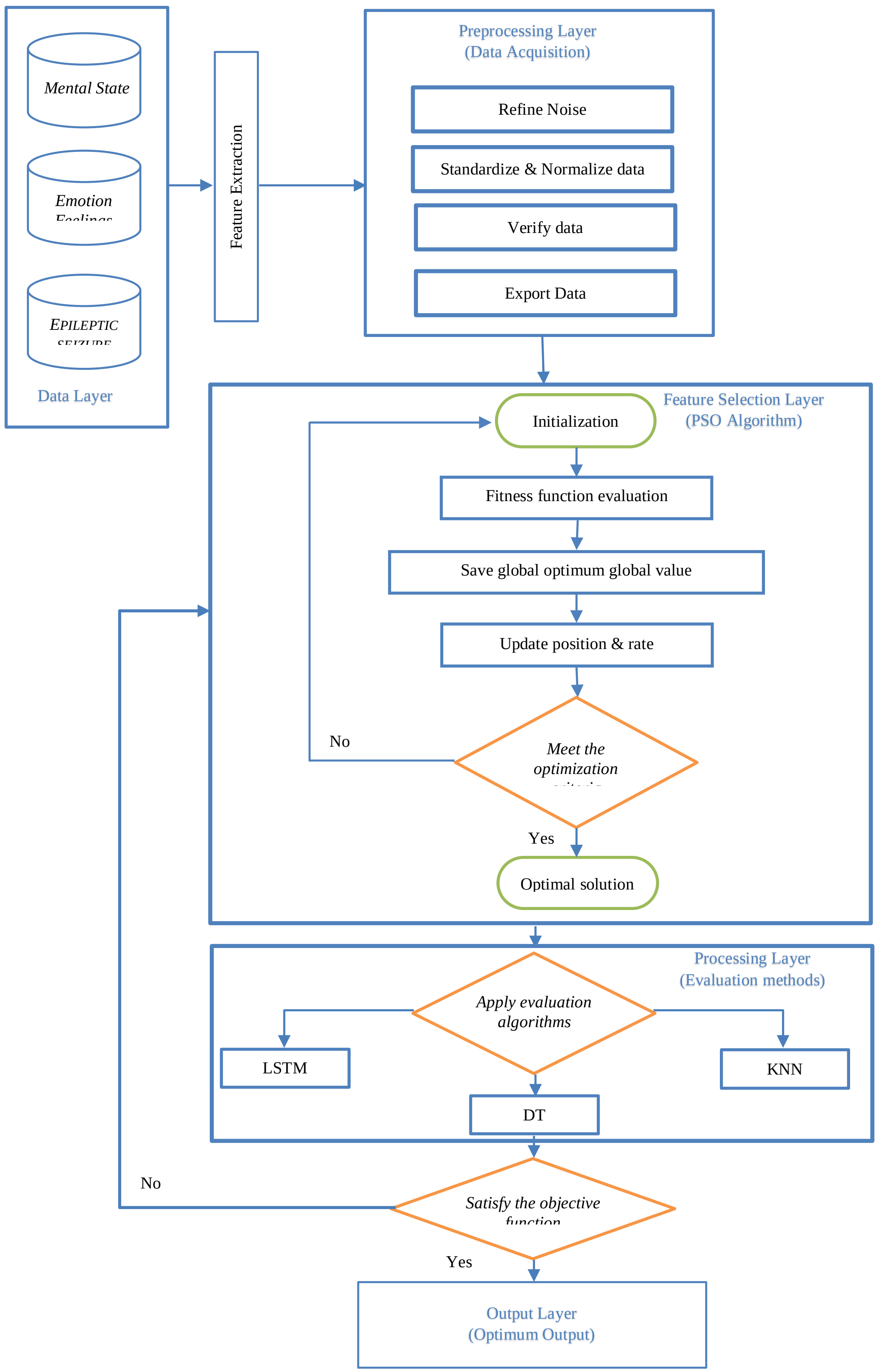

Fig. 4. Proposed Model.

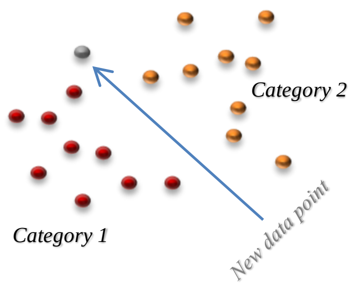

Fig. 5. KNN Classifier.

K-Nearest Neighbors (KNN) Algorithm

1: For all samples, repeat the steps below:

2. measure the distance between all samples in the training data and sample x

$$\mathbf{Dist} = \sqrt[2]{\sum (\mathbf{X_i} - \mathbf{S_i})^2}$$

3: Distances are sorted ascendingly.

4: choose the first K parts

5: $\mathrm{Output}_X = \mathrm{majority}_{\mathrm{Class}}(\mathrm{parts})$

2) *Decision tree:* The Decision Tree Classifier is one such approach for multi-stage decision making (DTC). When a complicated problem is divided into subproblems, and then this process is repeated recursively, a decision tree is generated. In a decision tree, each leaf node is given a class label, the root node non-terminal nodes, as well as additional internal nodes, distinct records with various properties based on the attribute testing criteria [26]. An example decision tree structure is shown in "Fig. 6". The decision nodes are the X-variables. a and b indicate the borders of the attribute boundaries that divide the decision into three tree pathways, and nodes are associated with attributes, Nominal or numerical values are also acceptable. As the leaves of a tree, the Class variables allow the item under study to be classified [27].

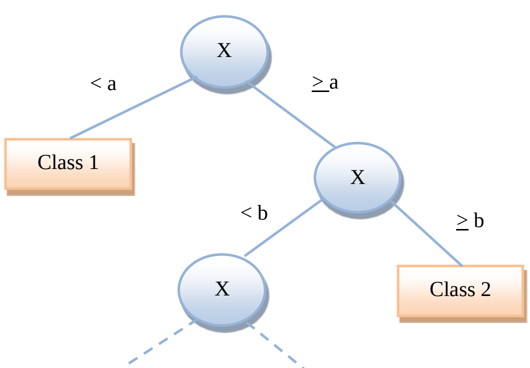

Fig. 6. Decision Tree Classifier.

Decision Trees (DT) Algorithm

Function BuildDecisionTree (DT,class,attributes)

Input DT: training instances, class: label of the class, attributes: array of attributes

Output: lower array and upper array limits for each attribute

Generate another node for root.

If all the instances fit in the same class, then

Return single root node with a label class

Else

Selected_Var ← CalcGiniIndex (DT, attributes)

// based on its Gini score, choose the feature in atts that best classifies occurrences

Root_decision_attribute ← Selected_Var

For all values of Selected_Var do

Add a new branch for the test Selected_Var =

Let it be the subset of DT which contain Selected_Var value

If found empty, then

Add Class label on a leaf node

Else

BuildDecisionTree(class,{attributes - Selected_Var})

Endif

End for

Endif

End

3) *Long short-term memory (LSTM):* It is a specific type of Recurrent Neural Networks called LSTM (RNN). This type of network has loops, and information is transferred from one loop to another. To utilise RNN for sequences and lists, such as time series, this chain-like character becomes apparent. Long-term dependencies, however, are an issue with conventional RNNs [28]. Information may be lost as a result of this as the distance between loops increases. A recurring module in the LSTM allows it to learn long-term dependencies. "Fig. 7" shows the construction of a typical RNN and LSTM that were employed in this research. Due to its benefit in learning long-term dependencies of time series, the LSTM algorithm was chosen; a temporal correlation analysis of EEG data is performed using this technique in this study [29].

A unique memory unit created by LSTM preserves historical information, while three gates regulate the updating and using of that knowledge: input gate, forget gate, output gate [30]. Fig. 7, an LSTM memory cell is shown in an illustration. It is implemented using the following composite function in this paper:

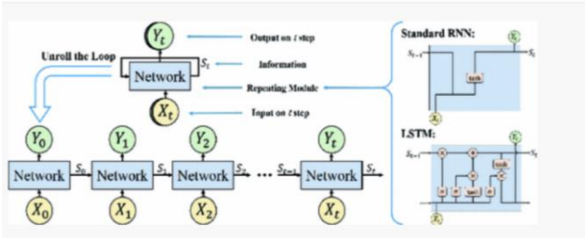

Fig. 7. The Typical Structure of an LSTM Block [30].

Long Short-Term Memory (LSTM) Algorithm

Input:

$$X_t, C_{t-1}, h_{t-1}$$
$$x_t: Current\ Input;\ C_{t-1}: Memory\ from\ last\ unit,;$$
$$h_{t-1}: output\ from\ last\ unit$$

forget gate phase for C_{t-1}

$$f_t = Sigmid\left(Weight_f[h_{t-1}, X_t] + bias_f\right)$$

update the new cell state phase

$$i_t = Sigmid(Weight_i[h_{t-1}, X_t] + bias_i)$$
$$N_t = Tanh(Weight_n[h_{t-1}, X_t] + bias_n)$$
$$C_t = C_{t-1}f_t + N_t i_t$$

the output phase:

$$O_t = Sigmoid(Weight_o[h_{t-1}, X_t] + bias_o)$$
$$Output_t = O_t \tanh(C_t)$$

End

VI. Experiment and Result

A. *Results of EEG Brainwave Dataset: Mental State*

By analyzing the KNN, DT and LSTM learning algorithms on the datasets in “Section III”, it’s clear that the LSTM achieved the best accuracy results of 97.0% compared to the other classifiers shown in “Fig. 8”. However, when applying the PSO on the EEG brainwave dataset: mental state dataset, in “Fig. 9” it’s obvious that the PSO performed higher accuracy result of 99.3%, when applied with LSTM classifier compared to the results when applied with the KNN and DT algorithms which were 96.1% and 95.3% respectively which emphasizes that the PSO enhanced the accuracy result by 2.3% than that resulted when applying the same algorithm without the PSO algorithm.

B. *Results of EEG Brainwave Dataset: Feeling Emotions*

By analyzing the KNN, DT and LSTM learning algorithms on EEG brainwave dataset: feeling emotions in “Section IV”, it’s clear that the LSTM achieved the best accuracy results of 96.08% compared to the other classifiers shown in “Fig. 10”. However, when applying the PSO on the EEG brainwave dataset: mental state dataset, “In Fig. 11” it’s obvious that the PSO performed higher accuracy result of 98.7 %, when applied with LSTM classifier compared to the results when applied with the KNN and DT algorithms which were 93.12% and 91.98% respectively which emphasizes that the PSO enhanced the accuracy result by 2.1% than that resulted when applying the same algorithm without the PSO algorithm.

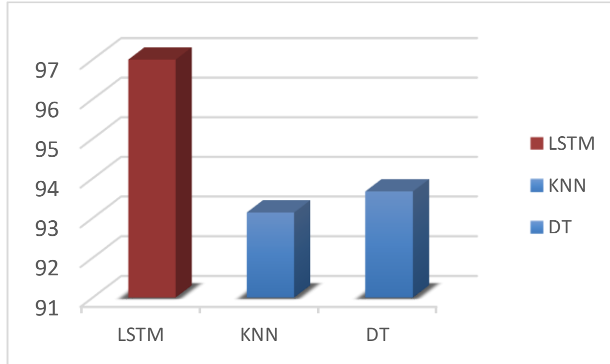

Fig. 8. Applying three different Learning Algorithms on A.Brainwave Dataset: Mental State.

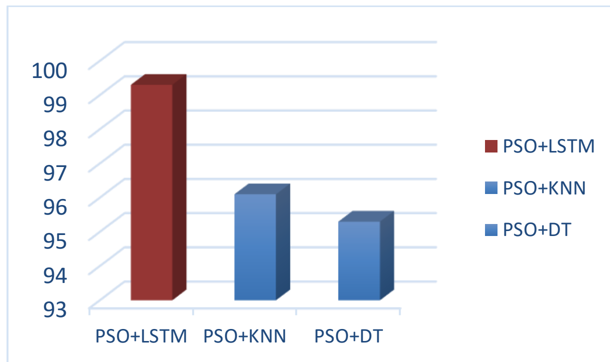

Fig. 9. Applying PSO with three different Learning Algorithms on a Brainwave Dataset: Mental State.

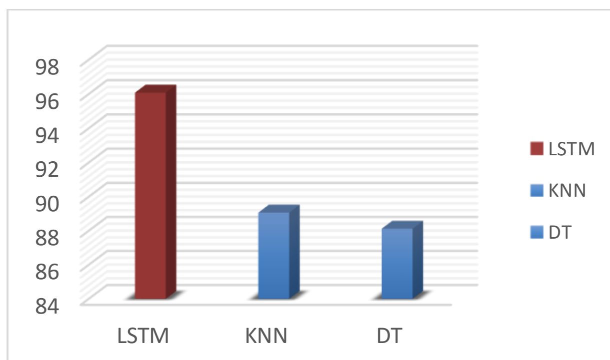

Fig. 10. Applying three different Learning Algorithms on Brainwave Dataset: Feeling Emotions.

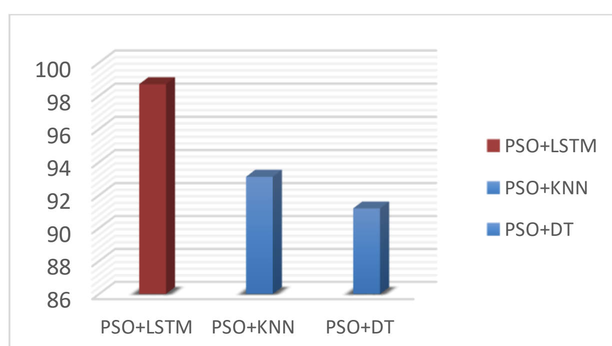

Fig. 11. Applying PSO with three different Learning Algorithms on Brainwave Dataset: Feeling Emotions.

C. Epileptic Seizure Recognition Dataset

By analyzing the KNN, DT and LSTM learning algorithms on EEG brainwave dataset: feeling emotions in "Section III", it's clear that the LSTM achieved the best accuracy results of 96% compared to the other classifiers shown in "Fig. 12". However, when applying the PSO on the EEG brainwave dataset: mental state dataset, in "Fig. 13" it's obvious that the PSO performed higher accuracy result of 99.1%, when applied with LSTM classifier compared to the results when applied with the KNN and DT algorithms which were 94% and 95.3% respectively which emphasizes that the PSO enhanced the accuracy result by 3.1% than that resulted when applying the same algorithm without the PSO algorithm.

After applying PSO to the three mentioned datasets we found that using PSO in feature Extraction is improved results after classification phase, PSO-LSTM model give best accuracy results when applied in the three datasets as shown in "Fig. 14".

By comparing this study with other previous experiments that used the same datasets we proved that the proposed models (PSO-KNN, PSO-DT, PSO-LSTM) produce the best accuracy compared with other models as shown in "Table II".

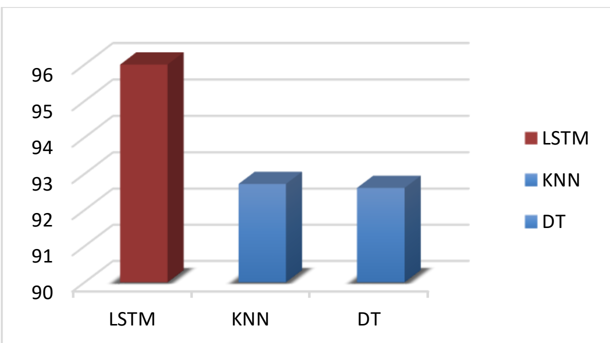

Fig. 12. Applying three different Learning Algorithms on Epileptic Seizure Recognition Dataset.

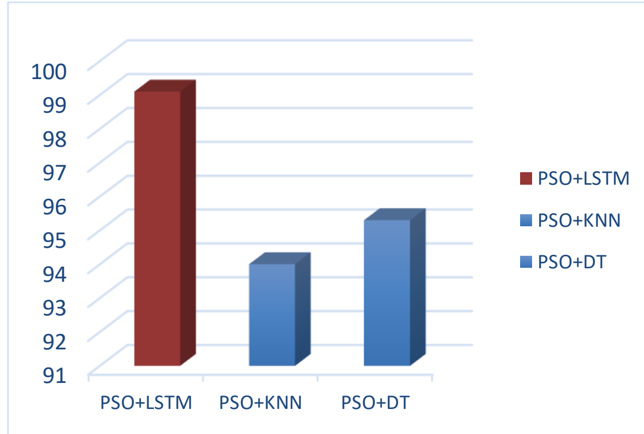

Fig. 13. Applying PSO with three different Learning Algorithms on Epileptic Seizure Recognition Dataset.

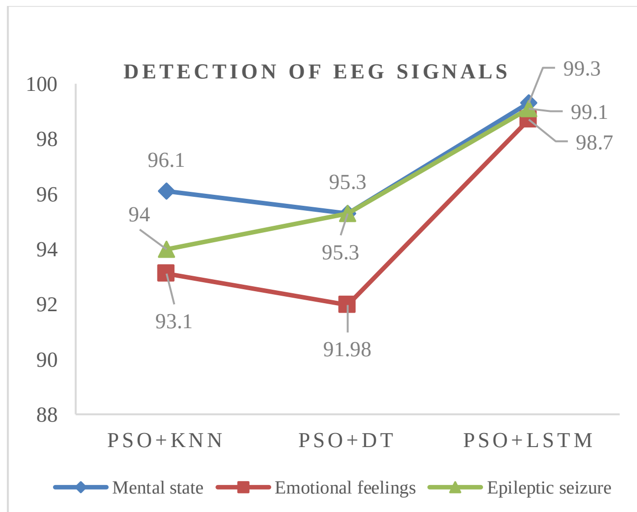

Fig. 14. Detection of EEG Signals from three Datasets using PSO Algorithm.

TABLE II. COMPARISON WITH OTHER STUDIES WITH THE SAME DATASETS

EEG brainwave dataset: Mental State			EEG brainwave dataset: Feeling Emotions			**Epileptic seizure recognition dataset**		
Study	**Method**	**accuracy**	**Study**	**Method**	**accuracy**	**Study**	**method**	**accuracy**
Chan, A., Early [11]	naive bayes bayes net random tree random forest SVM MLP	56.30% 73.6% 76.8% 78.1% 75.2% 80.8%	Bird, J. J., Faria[12]	AdaBoosted LSTM	97.06%	Acı, Ç. İ., Kaya,[34]	KNN SVM ANFIS	77.76% 91.72% 81.55%
Bird, J. J., Faria,[31]	AdaBoosted LSTM	84.44%	Bird, J. J., Ekárt,[33]	PRNG QRNG	65.35% 68.17%	Hosseini, S. A.,[35]	ANFIS	96.90%
Bird, J. J., Faria,[32]	2D CNN 3D CNN	93.89% 93.62%	Bird, J. J., Ekart[13]	InfoGain, RandomForest	97.89%	Mohamad Shahbazi[13]	STFT+CNN-LSTM	98%
This study	**PSO+KNN** **PSO+DT** **PSO+LSTM**	**96.1%** **95.3%** **99.3%**	**This study**	**PSO+KNN** **PSO+DT** **PSO+LSTM**	**93.1%** **91.98%** **98.7%**	**This study**	**PSO+KNN** **PSO+DT** **PSO+LSTM**	**94%** **95.3%** **99.1%**

VII. CONCLUSION

Machine learning techniques were used to classify EEG signals. In "Section III", we examined KNN, DT, and LSTM learning algorithms on the datasets. The LSTM obtained 97% accuracy on EEG brainwave dataset: mental state, 96% accuracy on EEG brainwave dataset: experiencing emotions, and 96% accuracy on Epileptic seizure identification compared to the others. KNN obtained 93.14 % accuracy on EEG brainwave datasets for mental state, epileptic seizure detection, and experiencing emotions, respectively. DT on EEG brainwave datasets for mental state, epileptic seizure detection, and experiencing emotions, the accuracy was 93.67%. Compared to other classifiers, PSO-LSTM obtained the brainwave dataset: experiencing emotions, and Epileptic seizure identification, respectively. PSO-KNN obtained 96.1 % accuracy on EEG brainwave datasets for mental state, epileptic seizure identification, and experiencing emotions, respectively, whereas PSO-DT achieved 93.12 % accuracy on the same datasets. The PSO algorithm improved the accuracy result by 2-3% when applied to the three distinct EEG brainwave datasets: mental state, epileptic seizure identification and experiencing emotions. So suggested model PSO-LSTM outperformed other models in accuracy.

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Fuzzy C-mean Missing Data Imputation for Analogy-based Effort Estimation

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***Abstract*—The accuracy of effort estimation in one of the major factors in the success or failure of software projects. Analogy-Based Estimation (ABE) is a widely accepted estimation model since its flow human nature in selecting analogies similar in nature to the target project. The accuracy of prediction in ABE model in strongly associated with the quality of the dataset since it depends on previous completed projects for estimation. Missing Data (MD) is one of major challenges in software engineering datasets. Several missing data imputation techniques have been investigated by researchers in ABE model. Identification of the most similar donor values from the completed software projects dataset for imputation is a challenging issue in existing missing data techniques adopted for ABE model. In this study, Fuzzy C-Mean Imputation (FCMI), Mean Imputation (MI) and K-Nearest Neighbor Imputation (KNNI) are investigated to impute missing values in Desharnais dataset under different missing data percentages (Desh-Miss1, Desh-Miss2) for ABE model. FCMI-ABE technique is proposed in this study. Evaluation comparison among MI, KNNI, and (ABE-FCMI) is conducted for ABE model to identify the suitable MD imputation method. The results suggest that the use of (ABE-FCMI), rather than MI and KNNI, imputes more reliable values to incomplete software projects in the missing datasets. It was also found that the proposed imputation method significantly improves software development effort prediction of ABE model.**

Keywords*—Analogy-based effort estimation; imputation; missing data; fuzzy c-mean

I. Introduction

Software development effort is considered one of the most significant metrics estimated in software projects due to the reasons that planning, developing, managing and all other important aspects of project depend extremely on accurate estimation of development effort[1]. Many effort estimation models have been introduced by researchers in software engineering domain , they can be classified into two major categories: first is parametric models which depend on statistical analysis of software projects data and assumed a linear relationship between effort and other project attributes, and second is Machine Learning (ML) models which depends on soft computing and artificial intelligence methods and assumed a non-linear relationship between effort and other project attributes [2, 3]. Among many ML models Analogy-Based Estimation (ABE) is a widely accepted estimation model since its flow human nature in selecting analogies similar in nature to the target project[4].

Missing data (MD) in software engineering datasets is major problem that affects the performance of effort prediction models [5, 6]. Many techniques are proposed to solve this problem includes : deletion, toleration, and imputation of missing data [7]. Missing data imputation is the most investigated technique in software effort estimation and KNN imputation was the popular adopted method [8].

Almutlaq and Jawawi [9], classified missing data imputation challenges for software effort estimation into two major categories, the categories are performance oriented and dataset challenges. Performance oriented challenges refers to challenges and issues that exist within the techniques itself on a performance level (missing data Accuracy, Model performance accuracy, and time efficiency). While the dataset challenges revolve around the role of the dataset and its effect on the missing data imputation techniques (numerical data imputation, categorical data imputation, dataset characteristics and size variety, and MD Mechanism Variety).

MI and KNNI are the most prominent missing data imputation techniques that have been used for ABE model [8]. MI method is considered as static imputation without analyzed the dynamic nature for each missing case in the feature concerned [10, 11]. KNNI depends on neighbor cases which may be related or not to the missing project values and derived a dynamic imputation value for each missing case for the feature concerned in the uncompleted dataset[12].

Identification of the most similar donor values from the completed software projects dataset for imputation is a challenging issue in the existing missing data techniques adopted for ABE model. Clustered completed software projects into homogeneous clusters based on the selected dataset attributes, and then identify more reliable donors cases to the incomplete project to impute missing values based on clustered data have not been yet investigated in ABE domain.

This study concerns on improve the performance of ABE model through adopting a new imputation method based on FCM technique. And compare empirically the results with KNN imputation and Mean Imputation (MI) for ABE model using different missing ratio of MNAR missingness mechanism.

Rest of the paper is organized as follow. Section II presents the concepts of ABE model, missing data, and techniques for handling missing data in software engineering datasets. Section III presents the concept of Fuzzy C-Mean clustering. Section IV presents related research studies for missing data techniques in software engineering domain and ABE model. Section V presents the proposed (ABE-FCMI) imputation technique. Section VI presents empirical evaluation design employed in this study. Section VII presents and discusses the reported results. Section VIII discusses internal and external threats to validity for this research study. Section IX concludes research findings and gives direction for some future work.

II. Background

This section presents the concepts of analogy-based effort estimation, missing data, and fuzzy c-mean (FCM) clustering.

A. Anolgy-Based Estimation (ABE)

Analogy based estimation proposed by Shepherd and Schofield as one of the most prominent non-algorithmic effort estimation model [13] .Comparison dependent process of comparing similar projects to the target project is done in order to derive the development effort in ASEE. Similarity measures are used to determine similar projects. Simplicity and estimation capability make it a widely accepted model in software effort estimation field. ABE consist of four parts:

- Historical completed software engineering projects dataset.
- Determine the level of similarity through Similarity Function.
- Estimate the software development effort by considering the similar projects found by the similarity function through solution function.
- Associated retrieval rules

The estimation process of ABE is accomplished in the following stages:

- A historical dataset in constructed based on the collected information of previous projects.
- For a comparison purpose select attributes are chosen.
- Retrieve similar projects to the target project based on the selected similarity function.
- Estimate the target project effort based on the selected solution function.

Similarity Function: Level of similarity between two projects is determined through similarity function that compares the attributes of both projects. Euclidian Similarity (ES) and Manhattan Similarity (MS) are two common similarity functions. (ES) function is represented in Equation 1.

$$Sim(p,p') = \frac{1}{\left|\sqrt{\sum_{i=1}^{n} w_i Dis(fi, fi') + \delta}\right|} \quad \delta = 0.0001$$

$$Dis(f_1, f_2) = \begin{Bmatrix} (f_1 - f_2') \; if \; f_1 \; and \; f_2' \; are \; numerical \; or \; ordinal \\ 0 \; if \; f_1 \; and \; f_2' are \; nominal \; and \; f_1 = f_2' \\ 1 \; if \; f_1 \; and \; f_2' are \; nominal \; and \; f_1 \neq f_2' \end{Bmatrix} \quad (1)$$

Where projects in comparison are p and p’ whereas Wight given to each attribute as wi. wight range between 0 and 1. The ith attribute of each project represented as fi and fi' and n represent the number of attributes. For gain none zero result δ is used. Solution Function: To derive software effort estimation based on most similar projects defined by similarity function a solution function is applied. Most dominant used solution functions are: inverse distance weighted mean [14] , closest analogy as the most similar project [15] , average of most similar projects [13] , median of most similar projects [16]. The median value of effort gained from K most similar projects, as K>2, described by Median. The average value of efforts gained from K most similar projects, as K>1, is described by Average.

B. Missing Data Concept

Missing data (MD) problem is a major challenge in software engineering datasets. Accurate software effort estimation depends strongly on the quality of datasets used for estimation process. In this subsection MD mechanisms and MD techniques (treatments) are elaborated.

C. Mechanisms of Missing Data

Missing data mechanisms are assumptions about the type and distribution of missing values [17].This identification of missing mechanism identify the missing treatment to be applied [7]. Three type of missing data mechanism are identified.

First Missing Completely At Random (MCAR) MD are independent of any variable observed in the data set, second Missing At Random (MAR) means that the MD may depend on variables observed in the data set, but not on the MD themselves, third (MNAR) in which the MD depend on the MD themselves and not on any other observed variable.

D. Techniques for Missing Data

Missing data treatment can be grouped in three methods as first MD deletion, second MD toleration, and third MD imputation.

MD ignoring (deletion) in this technique it simply handle the missing values by deleting them. MD deletion is properly suitable when the percentage of missing data is low. It is not utilize when consecutive data is missing like NIM (MNAR) mechanism [7, 18]. MD toleration in this method the missing value is assigned a NULL value and did not deleted from the dataset and the analysis is performed to same data [18]. MD imputation MD imputation method is employed to fill up the missing values and reaches a complete data set so that later this dataset can be utilized in enhancing the estimation of software development effort. KNN imputation is the most prominent method of imputation in software effort estimation [8, 19, 20].KNN provides a good result so far because it dost follow explicit mechanisms. Euclidean Distance and Manhattan Distance is used as a similarity measure to find nearest neighbors in KNN imputation methods.

III. Fuzzy C-Mean (FCM) Clustering

KNNI uses whole completed dataset for identifying similar neighborhood donor cases based on some distance measure, for ABE context it is important that donor cases to incomplete projects are come from similar projects in characteristics and nature to incomplete software project to impute missing values.

Clustering strategy as a data mining technique has been utilized recently to impute missing value. The idea behind using clustering in MD imputation is to impute incomplete record missing values from similar cluster that incomplete record located in, accuracy of imputation is improved by clustering data to groups with the same similarity features so that the range to substitute missing values is within cluster scope[21].

Clustering techniques can be divided into two major categories, hard clustering and soft (fuzzy) clustering. In hard clustering techniques, data object is belong to only one cluster which is the most similar cluster , however in fuzzy clustering a dataset object is belong to each one of clusters with a certain similarity given by membership function [22].

Hard clustering imputation techniques has been employed by many researchers such as k-means [23-25] in which incomplete data object missing values is imputed based on cluster information it is belong to. However in case of missing dataset there is uncertainty of incomplete data object is belonging definitely to certain cluster, so the need for fuzzy clustering imputation methods have been introduced such as FCMI [26-28] . The intra-variance in clusters is decreases by FCM compared to k-means algorithm [29] , moreover FCM is less sensitive to stuck on local minimum situation because of continuous membership function values [30]. Fuzzy imputation achieved higher performance compared to hard clustering imputation as denoted in experimental results [31].

Zadeh introduced the concept of fuzzy logic [23, 32]. Fuzzy logic is a computation approach based on degree of truth to represent uncertainty concept in information. Fuzzy theory and fuzzy set are introduced to solve the problem of imprecise information and uncertainty in missing data. Fuzzy capabilities are utilized to find plausible imputation values [31, 33, 34].

One dataset element can belong to two or more subsets in fuzzy clustering rather than crisp clustering. In FCM one dataset element can belong all clusters with different membership value associated to each clusters [35, 36].

Fuzzy C-Means (FCM) adopted recently in solving missing data problem [27, 28, 37]. Missing value can be derived by the calculated distance from clustered complete dataset based on obtained membership values.

This study focus on missing data imputation by clustering the completed projects into several clusters where they have similar connection between the features subsets.to best of our knowledge no research study has adopted FCM for ABE model.

FCM is a form of iterative algorithm. The goal of FCM is to find cluster centers (centroids) that minimize objective function (dissimilarity).The dissimilarity function (J) which is used in FCM is given Equation 2.

$$J = \sum_{i=1}^{n} \sum_{j=1}^{c} \mu_{ij}{}^{m} d_{ij}{}^{2} \tag{2}$$

μij is a membership function for i-th observation of the jth centroid, where $\sum_{i=1}^{n} \mu_{ij} = 1$

c is the number of clusters.

n is the number of observations.

dij is the Euclidian distance (||Xi-Cj||2) between ith centroid(ci) and jth observation.

m is the fuzzy degree ,m=2 is the general used value.

The cluster center (centroid) rj of jth cluster is given using equation 3.

$$rj = \frac{\sum_{j=1}^{c} \mu_{ij}{}^{m} xi}{\sum_{j=1}^{c} \mu_{ij}{}^{m}} \tag{3}$$

Compute the Euclidian distance and Update membership function μi j using equation 4.

$$\mu_{ij} = \frac{1}{\sum_{k=1}^{c} \left(\frac{d_{ij}}{d_{kj}} \right)^{2/(m-1)}} \tag{4}$$

The FCM algorithm can be elaborated as follow:

Algorithm 1: FCM Algorithm

REQUIRE: Input data to be clustered (X1, X2, , Xn). 2. Number of clusters (c), fuzzy degree value (m), maximum number of iterations allowed (I), the smallest desired error(ε),initial objective function (J0 = 0).
Step 1: Begin
Step 2: Initialize randomly membership function to each observation (μi j)
Step 3: Calculate centroid (cluster center) (rj) using equation 3
Step 4: Calculate the Euclidean distance, update the membership function (μi j) using equation 4
Step 5: Calculate objective function using equation 2
Step 6: Check for convergence criterion
IF (‖Ji − J(i − 1)‖) < ε OR (i > I) , then stop the process.
ELSE repeat step 2 to 6 until maximum iteration reached.
Step 7: END

IV. Related Work

The quality of past software dataset projects play major role in the performance of ABE model since it depend on historical past projects to predict the effort of target project. Researchers investigated missing data treatment techniques wildly in software engineering filed but few concentrate on ABE model. Idri, et al. [8] conducted a systematic mapping study in software engineering domain reviewed existing techniques treating missing data, it have been found that missing data imputation is the most used approach and KNN imputation is the most adopted method. Huang, et al.[6] Evaluated empirically data preprocessing techniques used for machine learning effort estimation models; the study validated missing data treatment techniques effectiveness to improve accuracy of prediction effort. Almutlaq and Jawawi [9] Reviewed recent missing data techniques in software effort estimation field, the study elaborated two major challenges that are imputation technique performance oriented and incomplete dataset oriented.

Strike, et al.[5] Investigated three missing data techniques (deletion, mean imputation, and hot-deck imputation) with three missing mechanisms (MCAR, MAR,and NIM) on regression effort estimation model.it have been found that hot-deck imputation outperformed other methods. Cartwright, et al.[19] Founded that KNN imputation has better results than mean imputation and missing data toleration in regression effort estimation model for MCAR missing data mechanism. Twala and Cartwright [20] combined KNN imputation with multiple imputation approach for Decision Trees effort estimation model, experimental results improved predictive accuracy of effort estimation using the proposed ensemble method. Sentas and Angelis [38] Investigated multinomial logistic regression (MLR) imputation for categorical missing data type in ISBSG dataset, the accuracy of regression estimation model improved especially with the case of high percentage of missing values. Li, et al.[18] Studied the relation between percentage of missing data (MCAR missing mechanism) and accuracy of AQUA model (form of ABE), the results confirmed a positive quadratic relation between percentage of missing data and accuracy of effort prediction. Song, et al.[7] Analyzed the impact of missing percentage and messing mechanisms on the accuracy of C4.5 effort estimation model using toleration and KNN imputation methods, the accuracy of prediction is severely affected in cases missing percentage above 40%. Idri, Abnane et al. [39] Conducted a study to evaluate prediction accuracy of ABE using different missing data techniques (toleration ,deletion ,and KNN imputation) with all missing mechanisms ,KNN imputation had superior improvement in ABE performance results.

Abnane and Idri [40] Investigated MD techniques (toleration, deletion, and KNN imputation) under different missing ratios and MD mechanisms for Fuzzy-ABE model using PRED (0.25) and SA as accuracy measures, they found that SA and PRED(0.25) measured different characteristics of technique performance. Huang, Li et al [41] Investigated data-preprocessing techniques (MD, normalization, feature selection) for ABE model under ISBSG dataset, KNNI improved ABE performance significantly compared to MI. Idri, Abnane et al [42] proposed SVR (Support Vector Regression) imputation, empirical results indicated that SVRI outperformed KNNI under different missing ratio and MD mechanisms for ABE model. Abnane and Idri [43] investigated mixed (Numerical and categorical) MD imputation techniques for ABE model, imputation techniques achieved better accuracy results, there is no significant difference between SVR and KNNI for mixed MD imputation. Muhammad Arif Shah [44] proposed Median Imputation of the Nearest Neighbor (MINN) for ABE mode , the investigation of the proposed model under Desharnais dataset outperformed both MI and KNN under MNAR mechanism.

Abnane, Hosni et al. [45] optimize parameters of KNN imputation using grid search, the optimize KNN imputation improved ABE significantly compared with regular KNN imputation. Abnane, Idri et al. [46] Proposed 2FA-KP-I (Fuzzy Analogy k-Prototypes Imputation) to impute mixed MD in ABE model, 2FA-KP-I outperformed KNNI under different missing ratio and MD mechanisms for ABE in the studied datasets.

Table I introduced literature review of MD techniques used in ABE model, it also summarized the type of MD, imputation methods used MD mechanism, and the findings for each study. As can be seen from Table I that KNNI and MI is the most used techniques. Literature review in Table I gives indication that the increased MD ratio negatively affected ABE performance, and MNAR MD mechanisms significantly decreased ABE performance.

MI method impute fixed value for all missing data in the same column (feature),this is done by replacing all missing value with the average value of the feature concerned. MI method is considered as static imputation without analyzed the dynamic nature for each missing case in the feature concerned, MI can alter the variance of the data and the relationships between variables does not preserved like correlation [10, 47, 48].

KNNI depends on neighbor cases of the missing value and derived a dynamic imputation value for each missing case for the feature concerned. KNN imputation have limitations related to : first not efficient for large dataset size ,second it imputes values based on the neighbors which may or may not be the related projects for donor values, third depend on parameter setting for KNN algorithm , and fourth KNNI performance is decreased with MNAR missingness mechanism [12, 39, 49, 50].

As can be seen from literature identification of the most similar donor values from the completed software projects dataset for imputation is a challenging issue in the existing missing data techniques adopted for ABE model. Clustered completed software projects into homogeneous clusters based on the selected dataset attributes, and then identify more reliable donors cases to the incomplete project to impute missing values based on clustered data have not been yet investigated by most researchers in ABE domain.

TABLE I. LITERATURE REVIEW OF MD TECHNIQUES IN ABE MODEL

Reference	Type of MD	Imputation Method	MD Mechanism
[18]	Numerical, Categorical	Toleration	MCAR
Finding	The results indicate that increased percentage of MD affected negatively accuracy prediction of AQUA (type of ABE model). The study suggested 40% upper limit of MD to get acceptable accuracy results of AQUA. The study suggested increased historical projects and attributes in the studied datasets to get better accuracy results of AQUA as MD percentage increased.		
[39]	Numerical	Toleration, Deletion and KNN imputation	MAR MCAR MNAR
Finding	KNN imputation improved ABE accuracy results compared to toleration or deletion of MD. The results shown that as the percentage of MD increased the accuracy of ABE is decreased .The results founded that the missingness mechanism affect the performance of ABE, accuracy of ABE is decreased significantly under MNAR compared to both MAR and MCAR.		
[40]	Numerical	Toleration, Deletion and KNN imputation	MAR MCAR MNAR
Finding	Fuzzy-ABE model have been got more accurate results using KNNI compared to deletion or toleration. PRED (.25) accuracy result confirmed SA measure. The results suggested to combine SA with other accuracy measure.		
[41]	Numerical	Mean imputation (MI) ,KNN imputation	Original missing values in ISBSG dataset
Finding	The investigated experimental results on ISBSG dataset concluded that KNN imputation as significant part of data-preprocessing stage improved the accuracy results of ABE compared to MI.		
[42]	Numerical	Support vector regression (SVR) imputation, KNN imputation	MAR MCAR MNAR
Finding	SVR imputation outperforms KNN imputation for both classical and fuzzy analogy effort estimation. The results shown that SVR imputation is less sensitive regarding MD percentage compared to KNN imputation. The results confirmed that for both SVR imputation and KNN imputation had worse performance under MNAR mechanism compared to both MAR and MCAR.		
[43]	Numerical and categorical MD	toleration, deletion, KNNI, SVR imputation	MAR MCAR MNAR
Finding	The results confirmed that imputation techniques achieved better accuracy improvements compared to toleration and deletion. In term of SA accuracy measure there is no significant difference between SVR and KNNI for mixed MD imputation. MNAR mechanism significantly affects ABE accuracy results for mixed MD imputation.		
[44]	Numerical	KNNI , MI , Median Imputation of the Nearest Neighbor (MINN)	MNAR
Finding	Experimental results reported that MINN outperformed both KNNI and MI for the studied Desharnais dataset. The results confirmed that there is no significant difference in accuracy improvement between KNNI and MINN due to the small size of the studied dataset. To generalize accuracy results there is a need to investigate large size datasets.		
[45]	Numerical	GS(Grid Search)-KNNI , E(Ensemble)-KNNI ,UC(Uniform Configuration)-KNNI	MAR MCAR MNAR
Finding	The proposed E-KNNI employed parameter optimization at imputation step. The results indicate that E-KNNI accuracy outperform GS-KNNI. E_KNNI and GS-KNNI had similar accuracy results. For MNAR mechanism E-KNNI significantly outperforms GS-KNNI.		
[46]	Numerical and categorical MD	2FA-KP-I (Fuzzy Analogy k-Prototypes Imputation), KNNI	MAR MCAR MNAR
Finding	The results found that 2FA-KP-I outperforms KNNI on four software engineering datasets under different missing ratio and MD mechanisms. Mean standard error (RMSE) is considered as imputation accuracy measure to evaluate competitive imputation techniques. The results indicate that MD mechanisms affected imputation accuracy for both 2FA-KP-I and KNNI, MNAR mechanism had significant impact on both.		

V. PROPOSED (ABE-FCMI) IMPUTATION TECHNIQUE

This section discusses the proposed (ABE-FCMI) imputation technique for imputing software engineering datasets. (ABE-FCMI) employed fuzzy clustering to divide the completed software projects into homogeneous clusters based on their features. Group completed data into similar features using FCM is the main operation to get for each feature the centroid value and obtain cluster centers finally.

The proposed (ABE-FCMI) method tries to solve gaps of, first selecting proper adjacent cases to derive the final missing data estimation value, and second improve ABE performance through MD imputation of MNAR missingness mechanism.

The basic idea behind using (ABE-FCMI) technique in ABE context is to impute incomplete software projects missing values based on homogeneous clustered completed software projects with high similarity within cluster and dissimilar with software projects in other clusters. Identification of similar donor cases for imputation is then assessed based on incomplete project membership values on each cluster.

In this study the idea of FCMI is borrowed from literature [27, 33] and applied to the problem of MD in ABE model to improve the prediction accuracy of software effort estimation.

The algorithm of the proposed (ABE-FCMI) method is as follow:

Algorithm 2: ABE - FCMI Algorithm

REQUIRE: Normalize the software projects dataset (D) using min-max normalization. Separate dataset (D) into two subsets: Complete software projects dataset (DC) and Incomplete software projects dataset (DM).
Step 1: **Begin**

Step 2: For all Complete software projects dataset (DC):
i. Calculate the cluster center (centroid) using Equation 3.
ii. Compute the Euclidean distance
iii. Update the membership function using Equation 1, 2, and 3.

Step 3: For all Incomplete software projects dataset(DM):
i. Calculate membership function to cluster centers that
are Calculated from step 2.

Step 4:For each incomplete software project calculate imputation value using membership value calculated from step 3 and cluster centers calculated from step 2.

Step 5 : End

The proposed (ABE-FCMI) algorithm imputes each incomplete project using information about membership function and the calculated cluster centers of completed projects. Generating of missing values using particular missingness mechanism and normalization of the dataset is taken in advanced before the imputation process started.

The processes of the proposed (ABE-FCMI) imputation method for ABE model is shown in Fig. 1 which include mainly : calculate cluster centers of complete software projects, calculate membership values for each incomplete software project, and estimate the imputed missing values. In first step the whole dataset is separated to complete and incomplete datasets. Cluster centers for complete software projects are calculated using FCM algorithm. In second step for each incomplete software project the membership values to given cluster center are calculated. In third step the imputation value is estimated based on membership values of incomplete software project calculated in second step and the cluster centers of complete software projects calculated in first step. The imputed dataset is used to evaluate the accuracy of prediction of ABE model as elaborated in Fig. 1.

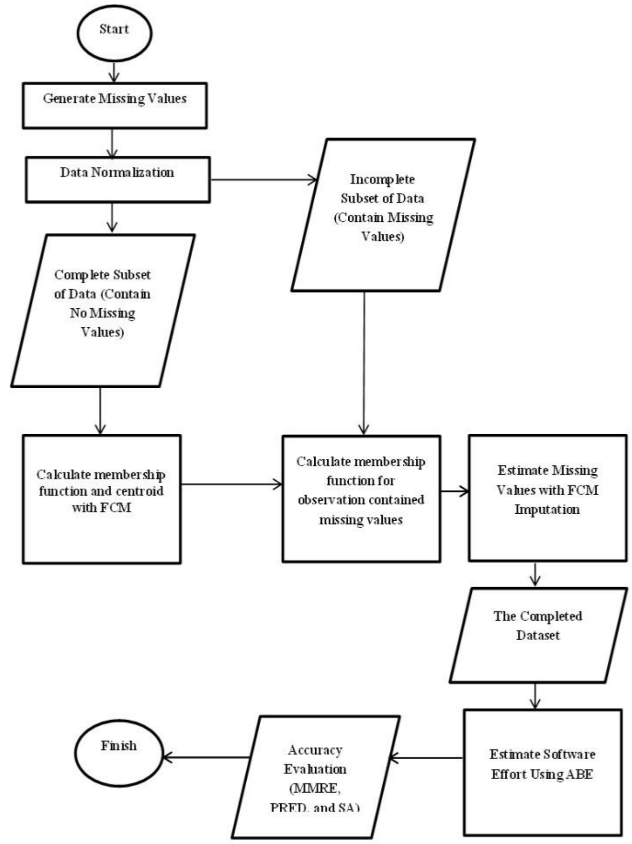

Fig. 1. The Proposed ABE- FCMI Method.

VI. Empirical Evaluation Design

In this section the empirical evaluation design is elaborated to define: first the datasets used in this study, second performance accuracy measures used to assess ABE prediction results, and third the adopted empirical process employed in this study.

A. Data Sets Description

Desharnais dataset as one of the most common datasets in the field of software effort estimation [51]. Recent research studies investigate Desharnais dataset imputation for ABE performance evaluation [39, 42, 44]. The data contain 81 software projects related to Canadian Software Company, 77 projects are complete with no missing values, and four projects are considered incomplete with some missing values. The data has nine features, all features are numerical except one feature which are language that are categorical. Effort feature is considered as dependent feature and other features are considered as independent features. The statistical details of Desharnais dataset is given in Table I. In projects number 38, 44, the TeamExp feature values are missing. In projects number 38, 66, and 75, the ManagerExp feature values are missing. The Histogram and pattern of missing data for Desharnais dataset can be seen in Fig. 2.

TABLE II. DESHARNAIS DATASET DESCRIPTION

Feature	Description	Min	Max	Mean	Std Dev
Effort	Development Effort in person-hours	546	23940	4923.516	4646.751
TeamExp	Team Experience in Years	0	4	2.244	1.331
ManagerExp	Manager Experience in Years	0	7	2.803	1.47
Length	Length of Project in months	1	39	11.716	7.4
Transections	Number of Transactions	9	886	179.901	143.315
Entities	Number of Entities	7	387	122.726	86.178
PointsAdjust	Number of Adjusted Function Points	73	1127	311.014	189.185
Envergure	Function Point Complexity Adjustment factor	5	52	27.014	10.851
PointsNonAdjust	Project Size Measured In Unadjusted Function Points. (Entities Plus Transactions)	62	1116	295.765	197.937

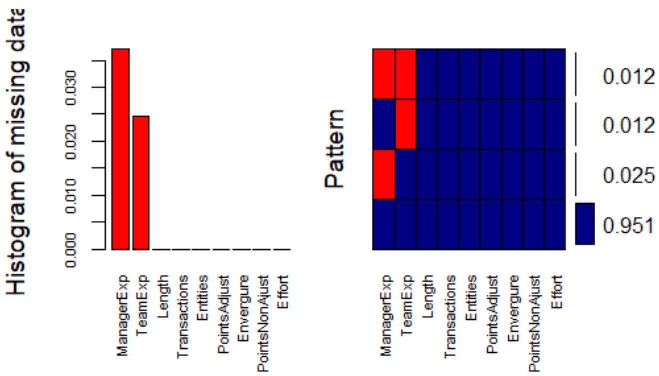

Fig. 2. Missing Data Histogram and Patterns for Desharnais Dataset.

The percentage of missing values in Desharnais dataset is relatively very low. In this study tow Desharnais datasets with different missing ratio are artificially created with MNAR missing mechanism to validate proposed missing data imputation methods for ABE model. Desh-Miss1 dataset 28.395% missing row ratio (23 out of 81 projects have missing values) and 3.33 % missing cell ratio (24 missing cells out of 720 cells) with MNAR missingness mechanism, and Desh-Miss2 dataset with 69.135 % missing row ratio (56 out of 81 projects have missing values) 7.916 % missing cell ratio (57 missing cells out of 720 cells) with MNAR missingness mechanism. Artificial missing data generation in software effort estimation has been performed in studies such as [18, 39]. The Histogram and pattern of missing data for Desh-Miss1 and Desh-Miss2 datasets can be seen in Fig. 3 and Fig. 4, respectively.

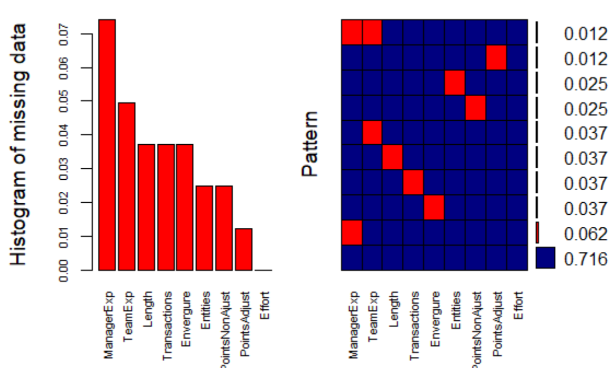

Fig. 3. Missing Data Histogram and Patterns for Desh-Miss1 Dataset.

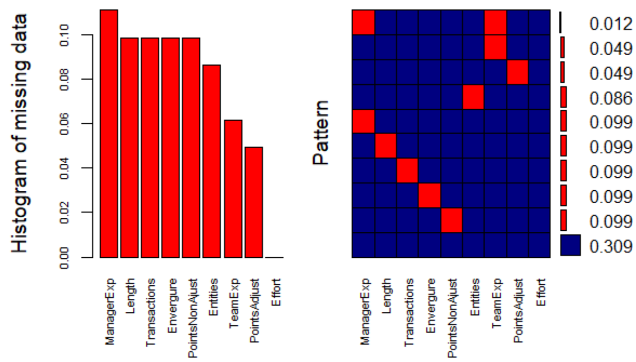

Fig. 4. Missing Data Histogram and Patterns for Desh-Miss2 Dataset.

B. Performance Accuracy Metrics

Several metrics have been used to evaluate the performance of estimation models which include Mean Magnitude of Relative Error (MMRE) measure that based on Relative Error (RE), and Magnitude of Relative Error (MRE) [13]. MMRE as most used evaluation metrics is defined as:

$$RE = (Estimated - Acutal)/Actual) \tag{6}$$

$$MRE = |Estimated - Actual|/(Actual) \tag{7}$$

$$MMRE = \sum_{i=1}^{N} MRE/N \tag{8}$$

Percentage of the prediction (PRED) is defined as:

$$PRED(X) = \frac{\mathrm{A}}{\mathrm{N}} \tag{9}$$

Where, A is the number of projects with MRE less than or equal to X and N is the total number of test set projects. Most effort estimation models are compared within X is 0.25 as acceptable value [52]. Shepperd and MacDonell [53] proposed SA measure that based on mean absolute error (MAE). SA considered as unbiased and standardized accuracy measure and gives an idea about the effectiveness of estimation model compared to random guessing.

$$MAR = \frac{\sum_{i=1}^{N} AEi}{N} \tag{10}$$

$$SA = 1 - \frac{MARp_i}{MARp_0} \tag{11}$$

Where MARp_i is the Mean Absolute Error of estimation technique p_i , and MARp_0 is the mean of a large number of random guesses (in our case 1000). The goal of estimation model is to minimize MMRE and maximizes PRED and SA prediction results for software effort estimation models.

Cross validation: Cross-Validation is introduced to give a more realistic accuracy evaluation to the estimation model. By dividing the historical dataset into multiple training and testing sets. These groups have almost equal size, one group is selected as test group and the remaining groups will be test groups. After that the estimation is computed for the test set and iteratively the process will be continued until all set are involved in the estimation , this depend of the number of sets. This insures the verification of all projects. Actually, all the projects are considered as a test case only once in all iterations. The final performance achieved from all the iterations is considered as mean value of performance metrics. MMREs, PREDs, and SAs mean values from all iteration is considered as MMRE, PRED, and SA final value.

C. Empirical Process

The empirical process adopted for this study is presented in fig. 5. As can be seen from Fig. 5, it is consists of four main steps: generating missing values, missing data imputation, ABE effort estimation, and accuracy evaluation. The design for the used empirical process followed similar approach used in [18, 39, 44] for evaluating the impact of MD imputation for ABE performance prediction.

Step 1: Generate missing values: in this study tow Desharnais datasets with different missing ratio are artificially created with MNAR missing mechanism to validate proposed missing data imputation methods for ABE model. Desh-Miss1 dataset with 28.395% missing row ratio (23 out of 81 projects have missing values) and 3.33 % missing cell ratio (24 missing cells out of 720 cells) with MNAR missingness mechanism, and Desh-Miss2 dataset with 69.135 % missing row ratio (56 out of 81 projects have missing values) 7.916 % missing cell ratio (57 missing cells out of 720 cells) with MNAR missingness mechanism. Artificial missing data generation in software effort estimation has been performed in studies such as [18, 39]. The Histogram and pattern of missing data for Desh-Miss1 and Desh-Miss2 datasets can be seen in Fig. 3 and Fig. 4 respectively. Table IV of Appendix presents a sample of the outcome (Desh-Miss2) of this step using MNAR mechanism with 69.135 % of MD on Desharnais dataset. Step 2: Missing data imputation: three imputation techniques (MI, KNNI, and (ABE-FCMI)) are used to impute missing values. The performances of these techniques are compared later to identify best imputation technique adopted for ABE prediction. Table XV of Appendix presents the outcome of the Step 2 using (ABE-FCMI) imputation under MNAR mechanism at 69.135% of MD on the sample data of Table XV. Step 3: Effort Estimation using ABE: software development effort using ABE model is predicted from the imputed dataset (complete dataset).Euclidian distance is used as similarity function and mean is used as solution function in ABE algorithmic procedure. Step 4: Accuracy evaluation: The performance of ABE is evaluated after each imputation technique to discover which imputation method outperforms the other. MMRE, PRED (0.22), and SA are used as accuracy estimation measures. Three-fold cross-validation is considered as evaluation method in ABE prediction model.

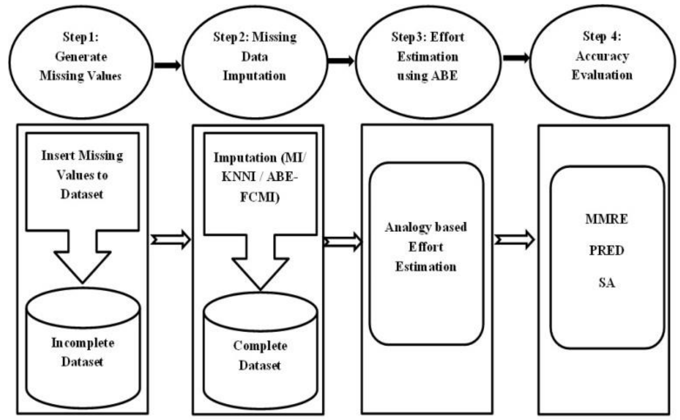

Fig. 5. Empirical Process for (MI, KNNI, and ABE-FCMI) Imputation Methods for ABE Prediction Model.

VII. Result and Discussion

This section presents the experimental results for evaluating ABE performance using three imputation methods (MI, KNNI, and (ABE-FCMI)) on Desharnais dataset with MNAR missingness mechanism and different missing ratio (Dish-Miss1,Dish-Miss2). First the experimental results for each incomplete dataset is evaluated individually, second a comparison between imputation methods is evaluated based on all given incomplete datasets.

A. Effects of MI, KNNI and ABE-FCMI on Desharnais Dataset

As discussed before Desharnais dataset contain missing values. In projects number 38, 44, the TeamExp feature values are missing. In projects number 38, 66, and 75, the ManagerExp feature values are missing. It can be concluded that Desharnais dataset have relatively lower number of missing values compared to other given incomplete datasets in this study. In step 1 Desharnais dataset is taken as incomplete dataset. In step 2 missing data imputation is performed using MI, KNNI, and (ABE-FCMI). In step 3 accuracy evaluation of ABE is measured for each imputation technique. Three-fold cross validation technique has been used to generate the results. The overall empirical process can be seen in Fig. 5. Table II shows MMRE results of imputation methods on ABE, while Table III shows the PRED(25) results of imputation methods on ABE, and Table IV shows SA results of imputation methods.

As seen in Table II, MI and (ABE-FCMI) achieved the lowest value of MMRE as 0.02622 and 0.02631 respectively with regard to the average of three folds. It is followed by KNNI where the value of MMRE is 0.02651. It is observed that the lowest value of MMRE is achieved by MI due to lower number of missing data in Desharnais dataset. Table III shows the PRED (0.25) results obtained from applying imputation methods to Desharnais dataset based on three-fold cross validation. As can be seen the PRED values are the same for all imputation methods. The SA results for imputation methods are given in Table IV. MI and (ABE-FCMI) achieved best SA results with values 56.66670, 56.49223 respectively, while KNNI achieved 56.38617 value for SA accuracy measure. It is observed that the best value of SA is achieved by MI due to lower number of missing data in Desharnais dataset.

TABLE III. MMRE RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESHARNAIS DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	0.01953	0.03234	0.02678	0.02622
KNN	0.02023	0.03266	0.02665	0.02651
ABE-FCMI	0.01979	0.03238	0.02672	**0.02631**

TABLE IV. PRED (0.25) RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESHARNAIS DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	33.33333	40.74074	37.03704	37.03704
KNN	33.33333	40.74074	37.03704	37.03704
ABE-FCMI	33.33333	40.74074	37.03704	37.03704

TABLE V. SA RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESHARNAIS DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	60.00657	50.91008	59.08344	56.66670
KNN	58.77629	50.69166	59.69057	56.38617
ABE-FCMI	59.38786	50.80258	59.28626	56.49223

B. Effects of MI, KNNI and ABE-FCMI on Desh-Miss1 Dataset

As discussed before Desh-Miss1 dataset have 28.395% missing row ratio (23 out of 81 projects have missing values) and 3.33 % missing cell ratio (24 missing cells out of 720 cells) with MNAR missingness mechanism. Desh-Miss1 dataset is incomplete dataset generated from Desharnais dataset.

As can be seen from Table V, (ABE-FCMI) achieved lower MMRE among all other imputation methods on ABE model with value (0.02589). It is followed by KNNI and MI with values 0.02608, 0.02634, respectively. (ABE-FCMI) archived higher PRED with value 38.27160 as given from Table VI. It is followed by KNNI and MI with the same value 35.80247. Best SA value is achieved by (ABE-FCMI) with value 56.97777 as observed from Table VII. The calculated SA values for KNNI, MI were 56.39966, 55.93544 respectively. As a result (ABE-FCMI) accomplished significant improvement compared to KNNI and MI on the selected accuracy evaluation measures (MMRE, PRED, and SA) for ABE estimation model applied for Desh-Miss1 incomplete dataset.

C. Effects of MI, KNNI and ABE-FCMI on Desh-Miss2 Dataset

As discussed before Desh-Miss2 dataset have 69.135 % missing row ratio (56 out of 81 projects have missing values) 7.916 % missing cell ratio (57 missing cells out of 720 cells) with MNAR missingness mechanism. Desh-Miss2 dataset is incomplete dataset generated from Desharnais dataset. As can be seen from Table VIII, ABE-FCMI achieved lower MMRE among all other imputation methods on ABE model with value (0.02557). It is followed by KNNI and MI with values 0.02693, 0.02794 respectively. The highest PRED values for all applying imputation methods on ABE for Desh-Miss2 dataset was achieved by (ABE-FCMI) with value 43.20988 as given from Table IX. It is followed by KNNI and MI with the same value 38.2716.

The SA results for ABE model on Desh-Missing2 after applying the selected imputation methods are given in Table X. ABE-FCMI accomplished best result for SA measure with value 56.92689. It is followed by KNNI and MI with values 56.80289, 55.80017 respectively. As a result, ABE-FCMI accomplished significant improvement compared to KNNI and MI on the selected accuracy evaluation measures (MMRE, PRED, and SA) for ABE estimation model applied for Desh-Miss2 incomplete dataset.

TABLE VI. MMRE RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESH-MISS1 DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	0.01954	0.0322	0.02728	0.02634
KNN	0.01935	0.03161	0.02728	0.02608
(ABE-FCMI)	0.01899	0.03225	0.02642	0.02589

TABLE VII. PRED (25) RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESH-MISS1 DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	29.62963	44.44444	33.33333	35.80247
KNN	33.33333	37.03704	37.03704	35.80247
(ABE-FCMI)	33.33333	40.74074	40.74074	38.27160

TABLE VIII. SA RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESH-MISS1 DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	59.04778	50.47609	58.28246	55.93544
KNN	60.2602	48.96933	59.96946	56.39966
(ABE-FCMI)	60.06159	50.91122	59.96049	56.97777

TABLE IX. MMRE RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESH-MISS2 DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	0.01908	0.03284	0.0319	0.02794
KNN	0.01887	0.03407	0.02785	0.02693
(ABE-FCMI)	0.018	0.03055	0.02816	0.02557

TABLE X. PRED (25) RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESH-MISS2 DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	37.03704	33.33333	44.44444	38.2716
KNN	40.74074	29.62963	44.44444	38.2716
(ABE-FCMI)	51.85185	29.62963	48.14815	43.20988

D. Comparison of Imputation Methods for ABE

A comparison between all selected imputation methods (MI, KNNI, and (ABE-FCMI) on all selected incomplete datasets (Desharnais, Dish-Miss1, and Dish-Miss2) for ABE estimating model is presented in Table XI. As the percentages of missing values are increased the calculated MMRE values for imputation methods are generally increased as shown in Table XII. For example MMRE values for MI are increased sequentially (0.02622, 0.02634, and 0.02794) for Desharnais, Desh-Miss1, and Desh-Miss2 incomplete datasets. Fig. 6 shows comparison based on MMRE values for MI, KNNI, and (ABE-FCMI) applied for ABE estimation model for all selected incomplete dataset in this study.it is observed that the MMRE values are increased as the number of missing values for incomplete datasets (Desharnais,Dish-Miss1,Desh-Miss2) are grown also.

As can be seen from Table XI, PRED values for MI and KNNI imputation methods have equal values as the percentage of missing data are increased. For example in Desharnias dataset PRED values for MI and KNNI are 37.03704. With increased number of missing values from Dish-Miss1 to Dish-Miss2 datasets, the PRED values for MI and KNNI are equal (35.80247) in Dish-Miss1 dataset, and also for Dish-Miss2 dataset with PRED value (38.2716) for MI and KNNI. Fig. 7 shows comparison based on PRED values for MI, KNNI, and (ABE-FCMI) applied for ABE estimation model for all selected incomplete dataset in this study.it is observed that (ABE-FCMI) improved significantly PRED values measure for Dish-Miss1 and Dish-Miss2 datasets with values 38.2716, 43.20988 respectively. It can be seen that (ABE-FCMI) successfully improve PRED measure although with increased number of missing values. MMRE and PRED are considered as biased accuracy measurements in ABE model and produced asymmetric distribution, there is a need for unbiased accuracy evaluation using SA measure [53-55]. A SA evaluation criterion is applied in this study for ABE estimation model. As can be seen from Table XI, the SA values are decreased as the numbers of missing values are increased from Desh-Miss1 to Desh-Miss2 incomplete datasets. For example the SA values for MI are 55.93544, 55.80017 respectively for Desh-Miss1 and Dish-Miss2. Another example the SA values for (ABE-FCMI) are 56.97777, 56.92689 respectively for Desh-Miss1 and Dish-Miss2.

Fig. 8 shows comparison based on SA values for MI, KNNI, and (ABE-FCMI) applied for ABE estimation model for all selected incomplete dataset in this study. As can be seen that the SA values are decreased as the number of missing values are increased, (ABE-FCMI) achieved the highest SA values in Desh-Miss1 and Dish-Miss2 with values 56.97777, 56.92689 respectively. For Desharnais dataset due to lower number of missing values (4 missing rows, 5 missing cells) compared to other incomplete datasets (Desh-Miss1, Desh-Miss2), (ABE-FCMI) achieved second highest SA value (56.49223). As a result (ABE-FCMI) achieved best results of the performance accuracy measures (MMRE, PRED, and SA) compared to MI and KNNI for ABE estimation model in incomplete datasets (Dish-Miss1, Dish-Miss2). Due to low number of missing cases in Desharnais dataset (ABE-FCMI) achieved second winner after MI method. The effectiveness of (ABE-FCMI) method to improve ABE accuracy result for Desharnais dataset is proven through the experimental part of this study. (ABE-FCMI) imputes missing datasets with more realistic values compared to MI and KNNI.

TABLE XI. SA RESULTS OF IMPUTATION METHODS ON ABE MODEL FOR DESH-MISS2 DATASET

Imputation Method	FOLD1	FOLD2	FOLD3	Average
Mean	60.36604	49.92606	57.10841	55.80017
KNN	61.1994	49.62232	59.58695	56.80289
(ABE-FCMI)	62.36436	50.74684	57.66948	56.92689

TABLE XII. COMPARISION OF (MI, KNNI, AND (ABE-FCMI)) IMPUTATION METHODS FOR (DESHARNAIS, DESH-MISS1, AND DESH-MISS2) FOR ABE MODEL

DATASET	MI			KNNI			(ABE-FCMI)		
	MMRE	PRED(25)	SA	MMRE	PRED(25)	SA	MMRE	PRED(25)	SA
1	0.02 622	37.0 3704	56.6 6670	0.02 651	37.0 3704	56.3 8617	0.02 631	37.0 3704	56.4 9223
2	0.02 634	35.8 0247	55.9 3544	0.02 608	35.8 0247	56.3 9966	0.02 589	38.2 716	56.9 7777
3	0.02 794	38.2 716	55.8 0017	0.02 693	38.2 716	56.8 0289	0.02 557	43.2 0988	56.9 2689

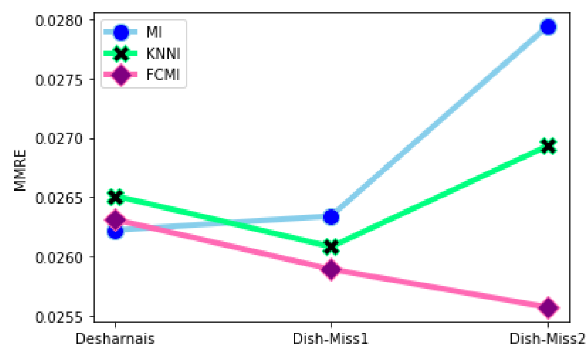

Fig. 6. Comparison of MMRE of (MI, KNNI, (ABE-FCMI)) for ABE Model.

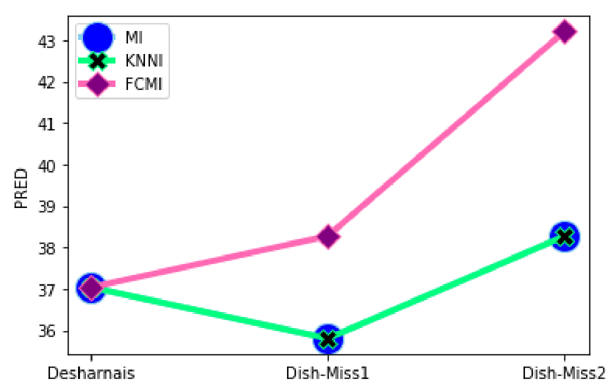

Fig. 7. Comparison of PRED (25) of (MI, KNNI, (ABE-FCMI)) for ABE Model.

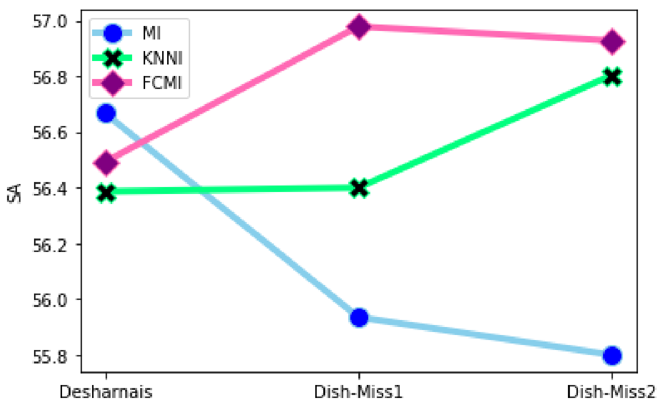

Fig. 8. Comparison of SA of (MI, KNNI, (ABE-FCMI)) for ABE Model.

VIII. Threats to Validity

In this empirical study, an evaluation of three imputation techniques using MNAR missingness mechanism and different MD percentages has been reported. It is difficult to carry out all possible scenarios, so some limitation may exist in this study.

A. Internal Validity

Internal validity is concerned with threats related to the scope of the study. In this study, an investigation attempted to simulate scenarios with MNAR missingness mechanism as well as different MD percentages. Generation of MD process for MNAR mechanism might considered as internal thread. A random selection of attribute for MD generation in the studied dataset is used. In this study we simulate tow incomplete datasets with different MD percentages; a threat might come from MD percentages as well as we investigate only MNAR mechanism.

B. External Validity

External validity is related to threats that are concerned with empirical design and result generalization. In this experimental study, we investigate Desharnais dataset as one of the most common datasets in the field of software effort estimation. Recent research studies investigate Desharnais dataset imputation for ABE performance evaluation [39, 42, 44]. Desharnais dataset is considered relatively small with 81 software projects only, and contained only numerical attributes, these might be considered as external threats, Table XIII.

IX. Conclusion and Future Work

The quality of the dataset plays a vital role for accurate software effort estimation process. Handling missing data problem is a major challenge to increase the quality of the dataset used for effort prediction. ABE as wide accepted effort estimation model depend mainly on the completed historically dataset for effort prediction, therefore confronting missing values in previously completed projects will improve the accuracy of ABE prediction. Different missing data imputation techniques have been used for ABE model including MI and KNNI. MI method is considered as static imputation without analyzed the dynamic nature for each missing case in the feature concerned in the incomplete software project. KNNI used Euclidian similarity measure to whole completed dataset to identify similar donor cases which may or not be related to the incomplete software project. In this study an imputation technique based on FCM clustering have been proposed for ABE model. The proposed (ABE-FCMI) technique is investigated for Desharnias dataset with different missing ratio and MNAR missingness mechanism. Experimental results suggest that ABE model using FCM imputation have provided significant improvement against ABE model using either MI or KNNI imputation methods. ABE Performance improvement of the proposed imputation method is based that FCM algorithm clustered software projects into homogeneous clusters based on the selected dataset attributes. Based on the completed dataset FCM algorithm identifies cluster centers. Imputation values for each incomplete project is calculated based on their distance and membership to the cluster centers identified before. (ABE-FCMI) identifies more reliable donors cases to the incomplete software project to impute missing values compared to KNNI and MI.

The Performance of ABE model has been positively affected with MD imputation techniques used in this study for incompleted datasets as seen in accuracy results. In comparison, (ABE-FCMI) significantly outperforms MI and KNNI in missing data imputation for ABE model in Desh-Miss1 and Desh-Miss2 incomplete datasets. For Desharnais dataset due to low number of missing values, there is no significant difference between the three imputations techniques used in Desharnais dataset. The fuzzy clustering nature of (ABE-FCMI) to identify groups of most similar projects indicate that it imputes more reliable values compared to MI and slightly better than KNNI on small datasets.

The study results have shown that as the percentage of missing data of MNAR mechanism increased from Desh-Miss1 to Desh-Miss2 incomplete dataset, the accuracy of ABE model is decreased using MI and KNNI imputation methods, however (ABE-FCMI) improved ABE accuracy although with increased percentage of missing data of MNAR mechanism.

The investigated software engineering dataset in this study is relatively small with 81 software projects only. We suggested investigating (ABE-FCMI) for large software engineering datasets to generalize our results. Numerical missing value imputation is the focus of this study; mixed (numerical and categorical) missing data imputation is required to verify the performance of (ABE-FCMI) method for ABE model.

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APPENDIX

TABLE XIII. SAMPLE DATA FROM ORIGINAL DESHARNAIS DATASET

TeamExp	ManagerExp	Length	Transactions	Entities	PointsAdjust	Envergure	PointsNonAjust	Effort
2.0	1.0	9.0	119.0	42.0	161.0	25.0	145.0	2569.0
1.0	2.0	**13.0**	186.0	52.0	238.0	25.0	214.0	3913.0
3.0	1.0	12.0	172.0	88.0	**260.0**	30.0	247.0	7854.0
3.0	4.0	4.0	78.0	38.0	116.0	24.0	103.0	2422.0
4.0	1.0	21.0	167.0	**99.0**	266.0	24.0	237.0	4067.0
2.0	**1.0**	17.0	146.0	112.0	258.0	40.0	271.0	9051.0

TABLE XIV. SAMPLE DATA OF INCOMPLETE DESHARNAIS DATASET (DESH-MISS2) OF STEP 1 USING MNAR MECHANISM WITH 69.135 % OF MD, WHERE NULL DENOTES THE REMOVED DATA

TeamExp	ManagerExp	Length	Transactions	Entities	PointsAdjust	Envergure	PointsNonAjust	Effort
NULL	1.0	9.0	119.0	42.0	161.0	25.0	145.0	2569.0
1.0	2.0	**NULL**	186.0	52.0	238.0	25.0	214.0	3913.0
3.0	1.0	12.0	172.0	88.0	**NULL**	30.0	247.0	7854.0
3.0	4.0	4.0	78.0	38.0	116.0	24.0	103.0	2422.0
4.0	1.0	21.0	167.0	**NULL**	266.0	24.0	237.0	4067.0
2.0	**NULL**	17.0	146.0	112.0	258.0	40.0	271.0	9051.0

TABLE XV. SAMPLE DATA OF (DESH-MISS2) OF STEP 2 IMPUTED USING (FCMI-ABE) IMPUTATION UNDER MNAR MECHANISM WITH 69.135 % OF MD. IMPUTED VALUES ARE INDICATED IN BOLD

TeamExp	ManagerExp	Length	Transactions	Entities	PointsAdjust	Envergure	PointsNonAjust	Effort
2.315	1.0	9.0	118.999	42.0	161.0	25.0	145.0	2569.0
1.0	2.0	**8.372**	186.0	52.0	238.0	25.0	214.0	3913.0
3.0	1.0	12.0	172.0	88.0	**217.154**	30.0	246.999	7854.0
3.0	4.0	4.0	78.0	38.0	116.0	24.0	103.0	2422.0
4.0	1.0	21.0	167.0	**91.639**	266.0	24.0	236.999	4067.0
2.0	**2.497**	17.0	146.0	112.0	258.0	40.0	270.999	9051.0

Simplified IT Risk Management Maturity Audit System based on “COBIT 5 for Risk”

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***Abstract*—In recent years, the role of risk management has emerged as a key success factor in ensuring the growth on the one hand and the survival on the other hand of any organization. Moreover, dependence on IT has become systematic within any organization. This dependence therefore, implies the importance of implementation of an IT risk management system in order to well manage IT risks. There are several standards that deal with enterprise risk management in general or information security in particular. However, few standards deal with IT risk management. Noting, for example, COBIT 5 (Control Objectives for Information and related Technology) which deals with IT risk management but is complicated to deploy. The purpose of this article is to describe a simplified IT risk management maturity audit system in an organization based on “COBIT 5 for risk”. This system aims to evaluate the maturity of IT risk management before proceeding to the implementation or update of an IT risk management system within an organisation.**

Keywords*—*IT risk management; COBIT 5 for risk; maturity audit system; COBIT 5 enablers; analysis axes; maturity scale and score; maturity audit report

I. Introduction

Taking risks is a prerequisite for the survival and growth of any business. By consequence, it is essential to properly manage and control the risks inherent in the activity, otherwise, if these risks arise, the company will not be able to achieve its objectives [1] [2].

On the other hand, with the emergence of Information Technology, which has become an integral part of any business ecosystem, IT risk management is becoming vital for the business [3].

“Risk management is a process that aims to reduce the harmful effects of an activity through conscious action to anticipate unwanted events and plan to avoid them. Risk management can be thought a process of measuring or evaluating risk and then designing strategies for risk management” [4] [5] [6] [7].

Therefore, standards have been developed to deal with risk management in general, IT risk management and information security in particular. Many risk management standards or information security standards exist, but few are the standards that deal with the question of IT risk management.

Noting for example, COSO, an internal control reference framework developed by the Committee of Sponsoring Organizations of the Treadway Commission and aims to improve the performance and governance of companies as well as reduce fraud within organizations [8].

On the other hand, there is the COBIT, a reference framework for IT audit and IT governance, is intended for management (which must decide on the investments to be made, to ensure the security and control of IT, and adjust them according to the risks of the environment) and the users (security, control of the IT services provided) [9] [10].

The COBIT 5 framework includes specific documentation for IT risk management called “COBIT 5 for Risk [11]” but this framework is complicated to deploy with a large library of publications requiring operationalization and consolidation of concepts related to IT risk management.

To respond to these limitations, we had focused our research on the development of a simplified IT risk management system that can be used easily within an organization. The first step in this development starts with the setting up of an IT risk management maturity audit system. The main purpose of this system is to evaluate the maturity of IT risk management, identify the gaps and define action plans that will allow the setting up or update of IT risk management within an organization. In this article we’ll describe a proposed system for IT risk management maturity audit within an organization based on “COBIT 5 for Risk”.

After an introduction, we will present a review of the literature on IT risk management. The next part will describe the methodological approach to be adopted when setting up the maturity audit system for the IT risk management of an organization. Afterwards, we will describe the proposed system for the maturity audit of the IT risk management of an organization. We will end with a conclusion and perspectives.

II. Review of the Literature on IT Risk Management

A risk can be defined as the “effect of uncertainty on objectives. An effect is a deviation from the expected - positive or negative. Uncertainty is the state, even partial, of deficiency of information related to, understanding or knowledge of, an event, its consequence, or likelihood.” [12] [13].

“COBIT 5 for Risk defines IT risk as business risk, specifically, the business risk associated with the use, ownership, operation, involvement, influence and adoption of IT within an enterprise. IT risk consists of IT-related events that could potentially impact the business. IT risk can occur with both uncertain frequency and impact and creates challenges in meeting strategic goals and objectives.” [11].

Risk management is the "coordinated activities to direct and control an organization with regard to risk". As a consequence, risk management framework is a "set of components that provide the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving risk management throughout the organization." [13].

Within the framework of risk management, several standards exist. Noting, for example, the COSO, a reference framework for internal control developed by the Committee Of Sponsoring Organizations of the Treadway Commission and aimed at improving the performance and governance of companies as well as reducing fraud within organizations. [8].

On the other hand, there is the COBIT which constitutes a reference framework for IT audit and IS governance and which is intended for both management and users. This framework includes dedicated documentation for IT risk management: "COBIT 5 For Risk" [11].

Regarding ISO 31000, it is a standard that provides principles and guidelines for risk management as well as the implementation processes at the strategic and operational level [14].

For ISO / IEC 27005, it is a standard that describes the main lines of risk management with a view to setting up an information security management system [15].

Below is a comparative table of a selection of existing standards related to risk management (Table I):

TABLE I. COMPARATIVE TABLE OF RISK MANAGEMENT FRAMEWORKS / STANDARDS

Framework / standard	**Enterprise Risk Management Framework / standard**	**IT Risk Management Framework / standard Framework**	**Information Security Risk Management Framework / standard k Management Framework / standard**
COSO	✓	×	×
ISO 31000	✓	×	×
ISO/CEI 27005	×	×	✓
COBIT 5	×	✓	×

Except COBIT 5, all of the frameworks / standards are either generic risk management frameworks, or specific frameworks for information security risk management and do not deal with all components of IT risk management. The COBIT 5 framework includes specific documentation for IT risk management called "COBIT 5 for Risk" but this framework is complicated to deploy with a large library of publications requiring operationalization and consolidation of concepts relating to IT risk management.

In addition, the COBIT 5 is a framework that aligns and incorporates the key components of other risk management frameworks [11] [10]:

- ISO 31000 (principles, Risk management Framework, process for managing risk).
- ISO/IEC 27005 (process).
- COSO (components, principles).

In the literature, there are research articles that discuss the COBIT 5 deployment for IT risk management. Authors "Walid Al-Ahmad" and "Basil Mohammed" in their article [16] present the business processes used in information security risk management, as well as the corresponding activities and guidelines for implementing them. This article does not take into account IT risk governance processes (EDM03 Ensuring risk optimization) and focuses on information security risk management. The authors "Hanim Maria Astuti et al." in their article [17] present a case study for the COBIT 5 deployment for the identification, assessment and management of IT risks of an organizational unit (Service Desk). This article is limited to the deployment of the two COBIT 5 processes: DSS02 Manage service and APO12 Manage Risks.

The main limitation noted of the two research articles cited above is that they partially cover the implementation of an IT risk management system and do not detail the IT risk governance process.

According to the different elements mentioned above, a research work has been launched for the development of an IT risk management system based on COBIT 5. This article presents the first phase of the development of this system and which consists of the description of a maturity audit system of the IT risk management of an organization.

III. Description of the Methodological Approach to be Adopted

In order to setting up a maturity audit system IT risk management within an organization, we suggest adopting an approach based on the analysis of the Risk Function perspective described by COBIT 5 for risk (Fig. 1). The Risk Function Perspective "describes what is necessary in a company to effectively and efficiently build and maintain governance and risk management activities". [11].

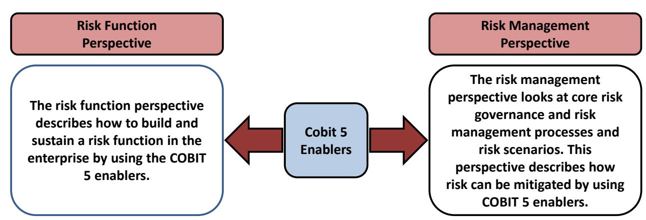

Fig. 1. The Two perspectives of Risk Proposed by COBIT 5 [11].

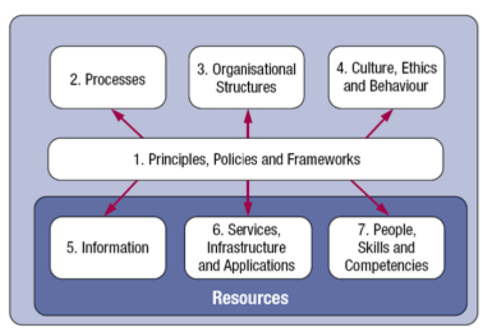

Fig. 2. The Seven COBIT 5 Enablers [9].

Indeed, the risk function perspective is based on the seven COBIT 5 enablers (Fig. 2) [9] in order to detail the different functions / dimensions of an organization that enable IT risk governance and management. An enabler can be considered as a dimension or a pillar for the establishment of IT governance.

The proposed methodological approach is broken down into seven macro-phases in alignment with the seven enablers defined by COBIT 5 (Table II.):

TABLE II. THE 7 MACRO-PHASES OF THE METHODOLOGICAL APPROACH TO BE ADOPTED FOR THE MATURITY AUDIT OF IT RISK MANAGEMENT WITHIN AN ORGANIZATION

Macro phase 1	Maturity audit of principles, policies and standards related to IT risk management
Macro phase 2	Maturity audit of IT risk management processes
Macro phase 3	Maturity audit of organizational structures related to IT risk management
Macro phase 4	Maturity audit of culture, ethics and behaviour related to IT risk management
Macro phase 5	Maturity audit of information related to IT risk management
Macro phase 6	Maturity audit of services, infrastructures and applications related to IT risk management
Macro phase 7	Maturity audit of people, skills and competencies related to IT risk management

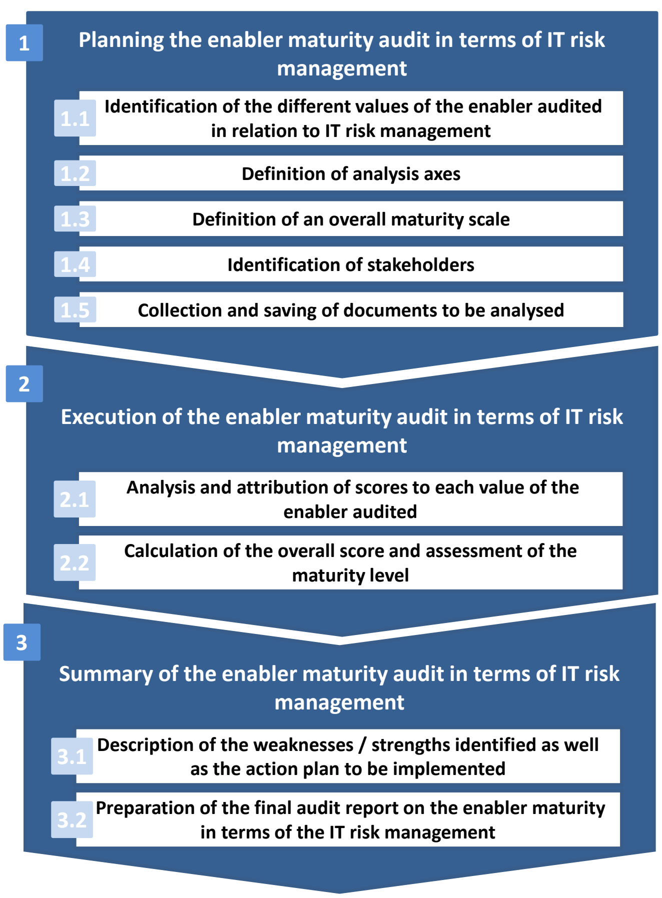

Fig. 3. Methodological Approach to be adopted to Audit IT Risk Management Maturity.

For each macro-phase, all of the steps described in Fig. 3 must be taken to audit the level of maturity of each enabler (Except the "Process" enabler whose maturity audit steps are partially described by the COBIT 5 [9]) in terms of IT risk management:

Step 1: Planning the enabler maturity audit in terms of IT risk management

Sub-step 1.1: Identification of the different values of the enabler audited in relation to IT risk management

For each enabler, the objective is to define its different values in relation to IT risk management in order to audit each value according to the defined axes of analysis.

Delivery: List of values of the enabler audited.

Sub-step 1.2: Definition of analysis axes

For each enabler, a set of good practices to be observed are specified by COBIT 5, on the basis of these good practices, the different axes of analysis are defined.

Delivery: List of axes of analysis.

Sub-step 1.3: Definition of an overall maturity scale

The maturity scale varies between 1 and 5. The definition of the value ranges included in each level is defined according to the minimum score and the maximum score of the enabler being audited.

Delivery: Global maturity scale.

Sub-step 1.4: Identification of stakeholders

We determine the various stakeholders necessary for the conduct of the enabler maturity audit in terms of IT risk management. For each value of the enabler audited, we define the business manager who will collaborate with the IT auditor in order to carry out the audit.

***Delivery*:** List of stakeholders.

Sub-step 1.5: Collection and saving of documents to be analysed

We collect and save the various documents to be analysed in order to audit the maturity of the IT risk management of the facilitator being audited.

***Delivery*:** Documents to analyse

Step 2: Execution of the enabler maturity audit in terms of IT risk management

Sub-step 2.1: Analysis and attribution of scores to each value of the enabler audited

We analyze each value of the enabler audited and assign a score per axis of analysis.

Delivery: Analysis and scoring table of the audited enabler.

Sub-step 2.2: Calculation of the overall score and assessment of the maturity level

We calculate the number and the percentage of the different scores assigned by axis of analysis and by value of the enabler audited (the number and the percentage of 0, 1 and 2). The overall score is calculated by summing all the scores. Depending on the overall score obtained, a maturity level is obtained in accordance with the previously defined maturity scale.

Delivery: Breakdown in percentage of scores 0, 1 and 2,

Overall maturity level of the enabler audited.

<u>Step 3: Summary of the enabler maturity audit in terms of IT risk management</u>

<u>Sub-step 3.1: Description of the weaknesses / strengths identified as well as the action plan to be implemented</u>

Based on the analysis of each value of the enabler according to the predefined axes of analysis, the strengths and weaknesses are identified as well as the action plan to be implemented to remedy the weaknesses observed.

Delivery: Summary of strengths and weaknesses and corresponding action plan.

<u>Sub-step 3.2: Preparation of the final audit report on the enabler maturity in terms of the IT risk management</u>

Prepare the maturity audit report for the enabler in terms of IT risk management, including a description of the various stages carried out and the audit results obtained.

Delivery: Enabler maturity audit report in terms of IT risk management.

IV. Description of the Proposed Simplified IT Risk Management Maturity Audit System

In this part, we will describe the simplified IT risk management maturity audit system in an organization by reviewing the different macro-phases. The first two macro-phases (Table II) will be described in detail; the others are similar to the first macro-phase except for certain steps which will be described below.

A. *Maturity audit of the Principles, Policies and Frameworks Related to IT Risk Management*

1) Planning of the maturity audit of the "Principles, policies and frameworks" enabler in terms of IT risk management

a) Identification of the different values of the enabler audited related to IT risk management

This step consists in identifying the principles and policies making it possible to build and implement IT risk management in an organization.

COBIT 5 defines seven principles in relation to IT risk management (Fig. 4) [18].

Regarding policies, COBIT 5 lists 18 policies with the description of each policy. Below are the 18 policies mentioned by COBIT 5 (Fig. 5) [11].

b) Definition of analysis axes: This step consists in determining the analysis axes based on the good practices of COBIT 5 [11]. The different axes of analysis and the corresponding rating system are described (Table III).

Fig. 4. Principles of Risk Management.

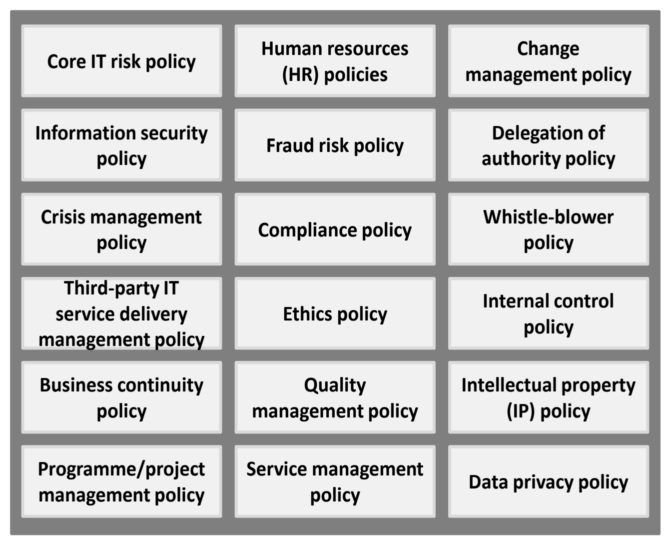

Fig. 5. The 18 Policies Defined by COBIT 5.

TABLE III. ANALYSIS AXES THE ENABLER "PRINCIPLES, POLICIES AND FRAMEWORKS"

Analysis axe	Description	Rating system		
		0	1	2
Existence	The existence of the policy audited	Non-existent	Partially existing	Totally existing
Corresponding principles	Correspondence between each policy and the 7 principles retained by COBIT 5	No principle corresponds to the policy to be audited	The policy to be audited corresponds to 1 or 2 or 3 principles	The policy to be audited corresponds to 4 or more principles
Scope	Description of the scope of application of the audited policy	Non-existent	Partially existing	Totally existing
Roles and responsibilities of the stakeholders	Description of the roles and responsibilities of the stakeholders of the audited policy	Non-existent	Partially existing	Totally existing
Consequences of non-compliance with the policy	Description of the consequences of non-compliance with the policy audited	Non-existent	Partially existing	Totally existing
Means for managing exceptions	Description of the means to be deployed to manage exceptions to the audited policy (for example: disciplinary measures, warning, etc.)	Non-existent	Partially existing	Totally existing
Approach adopted to ensure compliance with the policy	Description of the approach adopted to ensure compliance with the audited policy	Non-existent	Partially existing	Totally existing
Use of a recognized governance and management framework	The use of a recognized governance and management framework for the definition of the audited policy	No	Partially	Yes
Alignment with risk appetite	Alignment of the audited policy with the risk appetite determined by the organization	No	Partially	Yes
Regular update	The regularity of updating the audited policy	No	Partially	Yes

c) Definition of a global maturity scale

In this step, we define a maturity scale that varies between 0 and 5 and is divided between the minimum score and the maximum score (Fig. 6):

0	Maturity level 0	Rating 0
1	Maturity level 1	Rating between 1 and 72
2	Maturity level 2	Rating between 73 and 144
3	Maturity level 3	Rating between 145 and 216
4	Maturity level 4	Rating between 217 and 288
5	Maturity level 5	Rating between 289 and 360

Fig. 6. Global Maturity Scale of the Enabler "Principles, Policies and Frameworks".

d) Identification of stakeholders

In this step, we determine the various stakeholders necessary for the conduct of the maturity audit process of the macro-phase "maturity audit of principles, policies and frameworks related to IT risk management". For each policy, we define the business manager who will coordinate with the IT auditor in order to carry out the audit.

e) Collection and saving of documents to be analysed

In this step, we collect and save the various existing policies in order to analyze them and audit the maturity of the IT risk management of the "Principles, Policies and Frameworks" enabler.

2) Execution of the maturity audit of the "Principles, policies and frameworks" enabler in terms of IT risk management.

a) Analysis and attribution of scores to each value of the enabler audited

In this step, we analyze each policy according to the predefined analysis axes and we attribute a score per axe according to predefined rating system (Table IV):

TABLE IV. ANALYSIS AND ATTRIBUTION OF SCORES TO EACH POLICY ACCORDING TO PREDEFINED ANALYSIS AXES AND RATING SYSTEM

Policy	***Core IT risk policy***	***Third party IT service delivery management policy***
Existence	1	1
Corresponding principles	2	2
Scope	1	0
Roles and responsibilities	1	1
Consequences of non-compliance	1	0
Means for managing exceptions	1	1
Approach adopted to ensure compliance with the policy	1	1
Use of a recognized governance and management framework	1	0
Alignment with risk appetite	1	1
Regular update	1	0

b) Calculation of the overall score and assessment of the maturity level

This step consists in calculating the number and the percentage of the different possible scores (0, 1 and 2). Then calculating the overall score by summing all the scores awarded by value of the enabler and by analysis axe. The overall score makes it possible to assess the level of maturity of policies, principles and frameworks according to the positioning in the global maturity scale.

3) Summary of the maturity audit of the “Principles, policies and frameworks” enabler in terms of IT risk management.

a) Description of the weaknesses / strengths identified as well as the action plan to be implemented.

This step consists of positioning for each policy audited the scores assigned by analysis axe on a radar to better identify the strengths and weaknesses (Fig. 7).

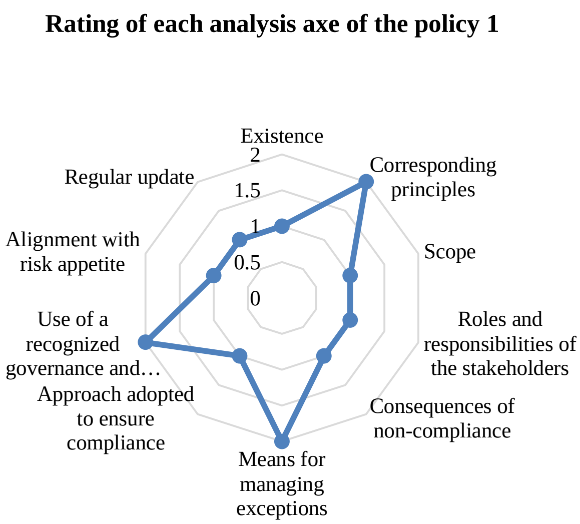

Fig. 7. Graphical Representation of Ratings Assigned to Policy 1.

Then, we proceed to the description of the strengths / weaknesses identified of each policy and we propose the action plans to be implemented to improve the level of maturity of the “Principles, Policies and Frameworks” enabler.

b) Preparation of the final report on the enabler maturity audit in terms of IT risk management.

In this step, the maturity audit report of the enabler “Principles, policies and frameworks” in terms of IT risk management is drawn up, with a description of the various stages carried out and the audit results obtained.

B. Maturity Audit of IT Risk Management Processes

The first step is to identify the processes needed for building and implementing IT risk management in an organization.

COBIT 5 defines 2 core processes dedicated only for IT risk governance and management [11] [19]:

- EDM03 Ensure Risk Optimization
- APO12 Manage Risk

COBIT 5 defines 12 supporting processes for IT risk governance and management (Fig. 8) [11] [19]:

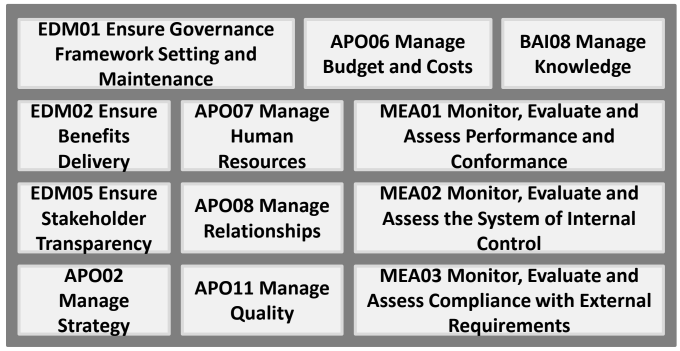

Fig. 8. Supporting Processes for IT Risk Governance and Management.

The rest of the 23 processes defined by COBIT 5 [19] also help in governance and IT risk management, but the contribution is low. These processes will therefore not be subject to a maturity audit.

The second step consists in determining the analysis axes, we retain the level of maturity of the process according to the maturity scale defined by COBIT 5. The level of maturity makes it possible to audit the maturity of a process, 6 maturity levels are defined in COBIT 5 (Fig. 9) [9]:

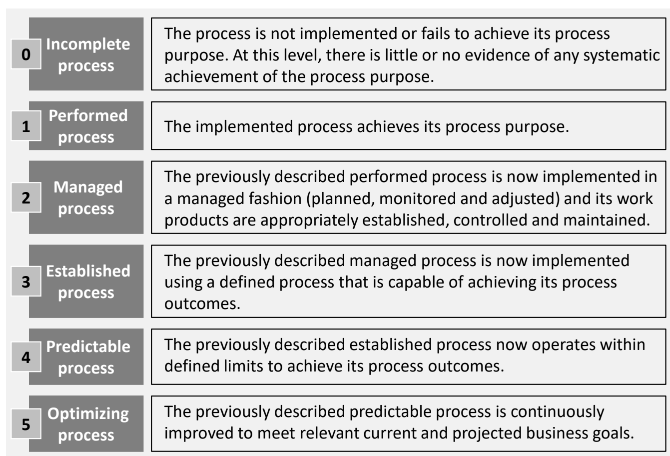

Fig. 9. Maturity Scale of Processes Defined by COBIT 5.

In the third step, we determine the different stakeholders necessary for the conduct of the process maturity audit. For each process, we define the business manager who will coordinate with the IT auditor to carry out the audit.

In the fourth step, we collect and save the documentation relating to existing processes in order to analyze and audit the maturity of the IT risk management of the “Process” enabler.

In the fifth step, we assess the maturity level of each process defined in the first step.

In the sixth step, the overall score is calculated by applying the following formula (1):

$$N_g = [60\%*(N_{cp1} + N_{cp2})+40\%*\Sigma\ (N_{spx})]/14 \quad (1)$$

- N_g: represents the overall score, the overall score makes it possible to assess the level of maturity of the processes according to the scale which varies between 0 and 5.
- N_{cp1}: represents the maturity of the first core process for governance and IT risk management (EDM03).
- N_{cp2}: represents the maturity of the second core process for governance and IT risk management (APO12).
- N_{spx}: represents the maturity of the 12 supporting processes for governance and IT risk management (list mentioned above).

In the seventh step, we proceed to the description of the strengths / weaknesses identified of each process and we propose the action plans to be implemented to improve the level of maturity of the enabler "process".

In the last step, we proceed to the preparation of the process maturity audit report in terms of IT risk management by resuming the various stages carried out and the audit results obtained.

In the remaining macro-phases going from 3 to 7, we only describe the two sub-steps "Definition of the analysis axes" and "Definition of a global maturity scale" of the planning step of the maturity audit. The rest remains similar to that of macro-phase 1.

C. *Maturity Audit of Organizational Structures related to IT Risk Management*

1) Definition of analysis axes: This step consists in determining the analysis axes based on the good practices of COBIT 5 [11]. The different axes of analysis and the corresponding rating system are described below (Table V).

2) Definition of a global maturity scale: In this step, we define a maturity scale that varies between 0 to 5 and is divided between the minimum score and the maximum score (Fig. 10).

0	Maturity level 0	Rating 0
1	Maturity level 1	Rating between 1 and 70
2	Maturity level 2	Rating between 71 and 140
3	Maturity level 3	Rating between 141 and 210
4	Maturity level 4	Rating between 211 and 280
5	Maturity level 5	Rating between 281 and 352

Fig. 10. Global Maturity Scale of the Enabler "Organizational Structures".

TABLE V. AXES OF ANALYSIS OF THE ENABLER "ORGANIZATIONAL STRUCTURES"

Analysis axe	Description	Rating system		
		0	1	2
Existence	Existence of the organizational structure to be audited	Non existent	Partially existent	Totally existent
Level of importance	Level of importance of the organizational structure to be audited: Core or supporting structure for IT risk management	Non existent	Supporting structure	Core structure
Operating principles	Description of the operating principles of the organizational structure to be audited	Non existent	Partially existent	Totally existent
Risk-based decisions	Taking into account the risks in the decision-making of the organizational structure audited	No	Partially	Yes
Span of control	Definition of the span of control of the organizational structure audited	No	Partially	Yes
Level of authority	Determination of the decisions that the organizational structure audited is authorized to take	No	Partially	Yes
Delegation of authority	Determination of the authorities that the organizational structure audited is authorized to delegate	No	Partially	Yes
Escalation procedures	Existence of a procedure for reporting incidents or problems encountered by the organizational structure audited	Non existent	Partially existent	Totally existent

D. Maturity Audit of Culture, Ethics and Behaviour related to IT Risk Management

1) Definition of analysis axes: This step consists in determining the analysis axes based on the good practices of COBIT 5 [11]. The different axes of analysis and the corresponding rating system are described (Table VI).

2) Definition of a global maturity scale: In this step, we define a maturity scale that varies between 0 to 5 and is divided between the minimum score and the maximum score (Fig. 11).

TABLE VI. ANALYSIS AXES OF THE ENABLER "CULTURE, ETHICS AND BEHAVIOUR"

Analysis axe	Description	Rating system		
		0	1	2
Communication	Communication inside the organization on the desired behaviour	No	Partially	Yes
Awareness	Awareness inside the organization of the desired behaviour	No	Partially	Yes
Incentives / deterrents	The existence of bonuses / penalties in relation to the desired behaviour	Non existent	Partially existent	Totally existent
Re-evaluation of expectations	The existence of a re-evaluation of management's expectations in relation to the behaviour audited on the basis of a gap analysis between the existing behaviour and that desired	Non existent	Partially existent	Totally existent
Rules and norms	Clear definition of rules and norms regarding the desired behaviour	No	Partially	Yes

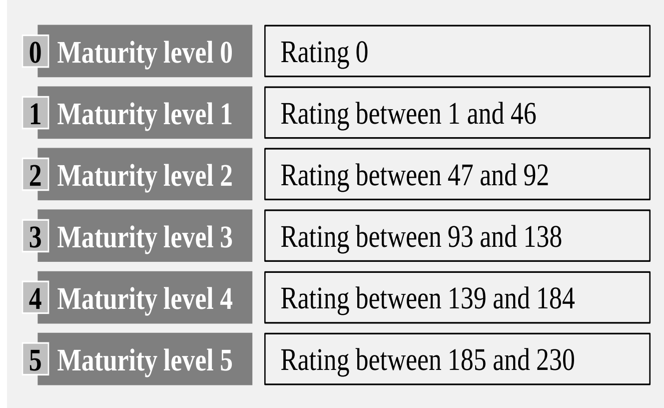

Fig. 11. Global Maturity Scale of the Enabler "Culture, Ethics and Behaviour".

E. Maturity Audit of the Information related to IT Risk Management

1) Definition of analysis axes: This step consists in determining the analysis axes based on the good practices of COBIT 5 [11]. The different axes of analysis and the corresponding rating system are described (Table VII).

2) Definition of a global maturity scale: In this step, we define a maturity scale that varies between 0 and 5 and is divided between the minimum score and the maximum score (Fig. 12):

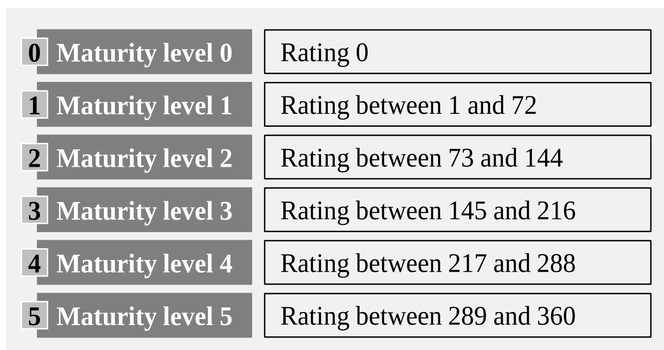

Fig. 12. Global Maturity Scale of the Enabler "Information".

TABLE VII. ANALYSIS AXES OF THE ENABLER "INFORMATION"

Analysis axe	Description	Rating system		
		0	1	2
Existence	Existence of the audited information	Non existent	Partially existent	Totally existent
Information carrier / media	"The attribute that identifies the physical carrier of the information, e.g., paper, electric signals, sound waves." The audit focuses on the quality of this attribute.	Bad	Medium	Good
Information access channel	"The attribute that identifies the access channel of the information, e.g., user interfaces." The audit focuses on the quality of this attribute.	Bad	Medium	Good
Code / language	"Attribute that identifies the representational language/format used for encoding the information and the rules for combining the symbols of the language to form syntactic structures." The audit focuses on the quality of this attribute.	Bad	Medium	Good
Information type	"The attribute that identifies the kind of information, e.g., financial vs. non-financial information, internal vs. external origin of the information, forecasted/predicted vs. observed values, planned vs. realised values." The audit focuses on the quality of this attribute.	Bad	Medium	Good
Information currency	"The attribute that identifies the time horizon referred to by the information, i.e., information on the past, the present or the future." The audit focuses on the number of time horizons concerned.	A single time horizon	Two time horizons	Three time horizons
Information level	"The attribute that identifies the degree of detail of the information, e.g., sales per year, quarter, month." The audit focuses on the quality of this attribute.	Bad	Medium	Good
Retention period	"The attribute that identifies how long information can be retained before it is destroyed." The audit focuses on the quality of this attribute (in terms of time and manner of conservation)	Bad	Medium	Good
Information status	"The attribute that identifies whether the information is operational or historical." The audit focuses on the quality of this attribute.	Bad	Medium	Good
Novelty	"The attribute that identifies whether the information creates new knowledge or confirms existing knowledge, i.e., information vs. Confirmation." The audit focuses on the quality of this attribute.	Bad	Medium	Good
Contingency	"The attribute that identifies the information that is required to precede this information (for it to be considered as information)." The audit focuses on the quality and availability of the prerequisites of the information subject to the audit.	Bad	Medium	Good
Context	"The attribute that identifies the context in which the information makes sense, is used, has value, etc., e.g., cultural context." The audit focuses on the quality of this attribute.	Bad	Medium	Good

F. Maturity Audit of Services, Infrastructures and Applications related to IT Risk Management

1) Definition of analysis axes: This step consists in determining the analysis axes based on the good practices of COBIT 5 [11]. The different axes of analysis and the corresponding rating system are described below (Table VIII):

TABLE VIII. ANALYSIS AXES OF THE ENABLER "SERVICES, INFRASTRUCTURES AND APPLICATIONS"

Analysis axe	Description	Rating system		
		0	1	2
Existence	Existence of the service / infrastructure / application audited	Non existent	Partially existent	Totally existent
Functional	Service / infrastructure / application audited is functional	No	Partially	Yes
Architecture principles	Definition of architectural principles (for example: reuse, simplicity, agility)	No	Partially	Yes
Architecture viewpoints	Definition of architectural points of view (for example: model, catalogue, matrix)	No	Partially	Yes
Architecture repository	Existence of the architecture repository	No	Partially	Yes
Service level by service provider	Definition of service levels to be achieved by service providers	No	Partially	Yes

2) Definition of a global maturity scale: In this step, we define a maturity scale that varies between 0 and 5 and is divided between the minimum score and the maximum score (Fig. 13):

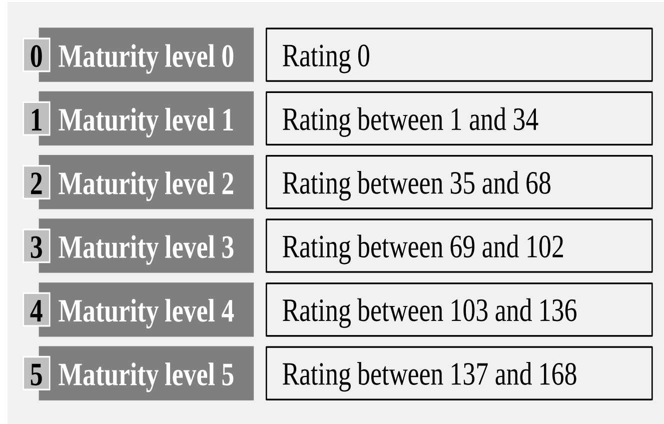

Fig. 13. Global Maturity Scale of the Enabler "Services, Infrastructures and Applications".

G. Maturity Audit of People, Skills and Competencies related to IT Risk Management

1) Definition of analysis axes: This step consists in determining the analysis axes based on the good practices of COBIT 5 [11]. The different axes of analysis and the corresponding rating system are described below (Table IX):

2) Definition of a global maturity scale: In this step, we define a maturity scale that varies between 0 and 5 and is divided between the minimum score and the maximum score (Fig. 14):

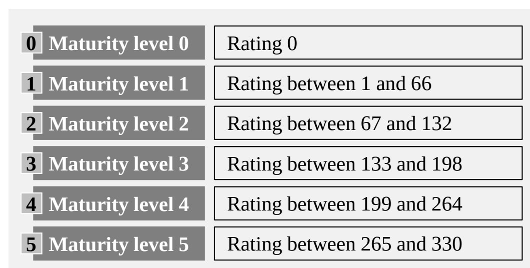

Fig. 14. Global Maturity Scale of the Enabler "People, Skills and Competencies".

TABLE IX. ANALYSIS AXES OF THE ENABLER "PEOPLE, SKILLS AND COMPETENCIES"

Analysis axes	Description	Rating system		
		0	1	2
Leadership skills	"Leadership skills include proactive leadership that sets clear direction that is aligned to the business outcomes and determination to ensure that the implemented policies deliver the effective disposition of risk."	Bad	Medium	Good
Analytical capability	"Capabilities to break down risk into risk factors that may prevent the achievement of goals and to assess those risk factors."	Bad	Medium	Good
Critical thinking	"Ability to make professional judgments about the value of additional information and determine whether a sufficient level of analysis has occurred is necessary."	Bad	Medium	Good
Interpersonal capabilities	"Ability to obtain information that is timely and accurate and to communicate with stakeholders who have different backgrounds and objectives."	Bad	Medium	Good
Communication	"Capability to communicate risk, risk factors, and the associated loss exposure in the context, language and priority of the relevant stakeholder."	Bad	Medium	Good
Influencing	"well-developed persuasion skills to help with adoption of risk practices across the enterprise and demonstrate value to stakeholders."	Bad	Medium	Good
Lateral thinking	"Risk needs to be approached differently depending on the type of risk."	Bad	Medium	Good
Technical understanding	"Basic understanding of the components comprising IT systems and how these components are connected to each other physically and logically."	Bad	Medium	Good
Organisational and business awareness	"To enable the enterprise to effectively plan, communicate and execute its risk management processes, the organisational points of contact, business units, goals, employee roles and responsibilities, and escalation paths must be documented and kept up to date."	Bad	Medium	Good
Risk expertise	"This skill refers to an understanding of the basic nature and composition of risk as well as ongoing improvement to keep pace with the dynamic nature of threats, vulnerabilities and impacts in the modern business environment."	Bad	Medium	Good
Training and coaching	"The ability to deliver targeted training programmes is essential in the successful update and sustainability of risk practices."	Bad	Medium	Good

V. CONCLUSION AND PERSPECTIVE

To respond to the limitations of existing standards dealing with IT Risk Management, we have defined in this article, a methodological approach to be adopted to conduct a maturity audit of IT risk management and we have presented a simplified IT risk management maturity audit system within an organization. The latter was built based on the best practices of "COBIT 5 for Risk" and by breaking down the seven enablers of COBIT 5 into seven macro-phases. The main purpose of the proposed system is to evaluate the maturity of IT risk management in an organization, identify the gaps and define the action plans to deploy in order to implement or update IT risk management within the organization. The simplified IT risk management maturity audit system proposed is declined into seven components to cover the different activities of an organization. The final delivery is a maturity audit report in terms of IT risk management covering the seven enablers defined by COBIT 5 (Fig. 2).

This work is a part of ongoing research for the development of a simplified IT risk management system. So, following the description of the IT risk management maturity audit system within an organization, we plan in a future work to design the system as well as to develop the IT solution that will support the execution of the audit steps.

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ExMrec2vec: Explainable Movie Recommender System based on Word2vec

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***Abstract*—According to the user profile, a recommender system intends to offer items to the user that may interest him. The recommendations have been applied successfully in various fields. Recommended items include movies, books, travel and tourism services, friends, research articles, research queries, and much more. Hence the presence of recommender systems in many areas, in particular, movies recommendations. Most current Machine Learning recommender systems serve as black boxes that do not provide the user with any insight into or justification for the system's logic. What puts users at risk of losing their confidence. Recommender systems suffer from an overload of information, which poses numerous problems, including high cost, slow data processing, and low time complexity. That is why researchers in have been using graph embeddings algorithms in the recommendation field to reduce the quantity of data, as these algorithms have been successful in the last few years. This work aims to improve the quality of recommendation and the simplicity of recommendation explanation based on the word2vec graph embeddings model.**

Keywords—Recommender system; explainable artificial intelligence machine learning; Word2vec

I. Introduction

With the advent of the internet today, we are witnessing an enormous information overload. This exponential growth in data results in difficulty organizing and analyzing this basic information but opens up new avenues on the paths of knowledge. The question is no longer to have the information but to find the relevant information simultaneously; from there, recommendation systems were born [1]. To manage the situation of information overload, graphs embeddings [2] appears as a solution that aims to present the properties of graphs in a vector or a set of vectors in a low-dimensional space while preserving the graph topology much as possible that offers more accurate recommendations. Graph embeddings can be classified into three main categories [3]: factorization graph embedding, random-walk graph embedding and deep graph embedding. Recommendation systems play an essential role in improving the user experience of online services to reduce the efforts of humans in the search for objects of interest. Examples of these systems include recommending a set of items such as Amazon products, advertisements from products presented by Google based on search history, movie recommendations from Netflix, Yahoo, Movies, and Movielens [4] [32].

It often happens that some recommended articles are not expected for users and thus cause confusion. Explainability, therefore, becomes a criterion closely linked to the quality of the recommendation system. Indeed, supporting the recommendations with explanations justifying the proposals helps to improve efficiency, transparency, and user satisfaction, which allows for better user loyalty. The literature offers some methods to generate explanations of recommendations; however, these methods have several limitations.

Explanations are not easy to obtain regardless of their importance. Indeed, with the recent success of the machine learning neural networks, the Recommender system relies increasingly on these algorithms because of the black-box nature of machine learning algorithms to improve their performance and predictions for transparency [4].

An emerging field called Explainable Artificial Intelligence [5] recently discussed the problem of deep learning explicitness and other transparent machine learning algorithms by providing methods that generate high-quality predictions aswell as intuitive explanations of the results.

Therefore, being aware of the importance of addressing information overload and explainability issues in recommender systems and under the background of the word2vec model and explainable artificial intelligence, we propose in this paper a word2vec-based approach for the explainable recommendation. Precisely, we extract relationships between movies from user history to build the vocabulary of the word2vec technique to make recommendations. Then we match these recommendations with a human-friendly explanation style. The rest of the paper is organized as follows:

1) We introduce the basics of this work, Recommender systems, Word2vec model, and Explainable Artificial Intelligence.

2) We analyze related works in this area.

3) We present our proposed approach, and we discuss how it helps present a simple explanation for a normal user through an illustrative example. We discuss experiments made to evaluate our proposition.

4) We present our conclusions and directions for the future.

II. Recommender Systems

Currently, there are many aspects of modern life, and we are being overwhelmed by this information large quantity, or this reason, recommender systems have been helpful since their birth in the mid1990s to address this wealth of data by suggesting to an active user in the field of his interests a list of objects or a unique object [6]. There are three main recommendation approaches (see Fig. 1) content-based recommendation, collaborative filtering-based recommendation, and hybrid recommendation [7].

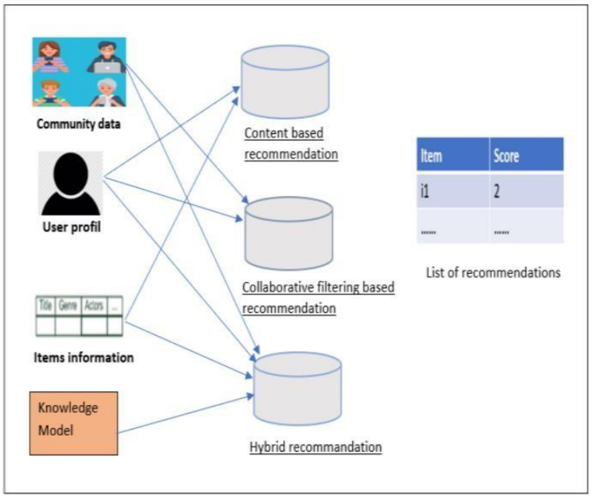

Fig. 1. Major Recommendation Approaches.

A. Content-based Recommendation

This approach works by analyzing the content of an item to compare it to a profile that describes the user's interests. For example, if the item description describes a certain kind of music, the system will compare that description to the user's profile to predict its usefulness [4]. A content-based recommendation system is a filtering system that uses elements description and user data to identify to users items that are most likely to appeal to them.

That is to say. It is an approach that uses the content of documents to compare them to a profile's themes. The system then learns about the user's interests and uses these details to predict the usefulness of a given document. For example, if the user likes or dislikes specific themes or attributes, the system will suggest a document with these characteristics [8]. Content-based recommendations have several advantages and disadvantages. The strengths of this approach are:

- User autonomy: Content-based recommendation techniques treat users independently. Thus, only the evaluations of each user are taken into account to build their user profile and make the recommendation [9].
- Immediate consideration of a new item: the recommendation of items based on content-based filtering is not necessarily linked to the evaluation by a user; the item can be recommended without being evaluated [10].

However, this approach tackles many challenges:

- Content analysis limited: this requires detailed descriptions of the items and a highly organized user profile to produce recommendations. Unfortunately, that does not always happen.
- Subspecialization of content: Users shall only receive recommendations similar to items already defined in their profiles.
- No immediate embarkation of a new user: before the system can interpret its preferences, a user must evaluate several items and make the appropriate recommendations.

Several content-based filtering solutions are available [11] we cited:

- News Dude: a personal data system using the synthesized language to read articles of users.
- LIBRA: is a book recommendation system based on the content that uses web-based book information. The system can explain anyrecommendation made to users that will enable them to trust the system's recommendations fully.
- Pandora: is a web-based radio (available in the United States only) which incorporates a Music Genome Project automated music recommendation service. Where the user first specifies an artist's name or a music title. The system then handles the rest of the music list and selects the titles closer to the first choice musically.

B. Collaborative Filtering based Recommendation

This method uses the history of ratings to predict future interests. It assumes that various people have common interests in multiple products, then those interests are likely to extend to other products [12]. Collaborative filtering is a recommendation algorithm that predicts articles (whatever they are, books, films, press articles) that users will appreciate in the future. This approach aims to predict what a person will like in the future. The algorithm uses the history of that user and all the existing information in the system about other users. These algorithms can detect users who have similar tastes to exploit this information for recommendations [1].

For example, suppose it turns out that Amina, Mouna, and Imad have liked similar songs in the past and that Amina listens or gives a favorable opinion on the last song of Salma Rachid. In that case, Mouna and Imad likely like it too, and it is relevant to recommend it to them. We can use the data in a collaborative filtering system in several ways. These methodologies are categorized into two prominent families: algorithms based on memory and models [4]. There are several advantages to the collaborative filtering-based recommendation approach; the most important are [10]:

- Surprise effect: The user may receive an appropriate surprise recommendation that is often desirable for himself. For instance, if user a is close to user b because he is only watching comedies and if b loves a different genre, the system will recommend this film because of its proximity.
- Domain knowledge not required: collaborative recommendation is based only on item scores. Therefore, it does not require any knowledge of items.

However, using this recommendation approach can lead to several issues:

- Cold start problem: There is no sufficient user or item information to make relevant predictions in the recommendation system. The cold start problem is one of the most significant limitations, which lowers system performance. This new user's profile or article is empty because it is not rated; its taste is thus unknown.
- Sparsity: a situation where users evaluate a little of the total number of articles available in a database. Wich leads to a sparse matrix with a rate of missing values that can reach 95% of the articles' inability to locate successful neighbors and the generation of weak recommendations. In addition, the scarcity of data.
- The gray sheep problem: Users with different tastes out of the ordinary will not have many similar users. So it will not be easy to make relevant recommendations for this kind of user.

Among the most popular collaborative systems we cited [11]:

- Ringo: is a system based on collaborative filtering that recommends music albums and artists. This system gives a list of 125 artists to the user when this user first enters the system to rate them according to his preference.
- Amazon.com: is an example of an e-commerce recommendation engine that utilizes scalable
- collaborative peer-to-article filters to recommendonline products for various product types. The algorithm of calculation evolves regardless of the user number and the object number.
- GroupLens: is a collaborative filtering system based on the client/server architecture; the system recommends News Usenet, a high-volume Internet discussion list service.

C. Hybrid Recommendation

A hybrid recommendation is another class of recommendation that seeks to overcome the limitations of the previously discussed other approaches. It combines two or more different techniques of recommendation. Content-based and collaborative filtering combination is the most popular hybrid technique. That is, the content of items and the ratings of all users are used [13].

As the name implies, the hybrid-based recommendation combines one or more of the preceding methods [14]. In addition, it solves challenges like cold start and sparsity by combining components from other recommendation systems or relying on their reasoning [15].

This type of recommendation tries to overcome the shortcomings of the previous two approaches. It is a synthesis of two or more different recommendation techniques [1]. There are several ways to do hybridization, and no consensus has been defined by the research community [16] to hybridize. However, Burke [17] identified seven different ways of hybridizing.

Among the most popular hybrid recommendation systems, we cited [11]:

- Netflix: an online movie service that allows users to rent movies for a monthly fee based on an inventory of priority movies they want to see. Films will be sent to users. If the user has finished watching the film, the system automatically returns the DVD by mail and mail the next DVD, free of post. The length of subscription for subscribers is related to the number of films they see and enjoy. If they do not find films that interest them, subscribers tend to drop out of service. Therefore, company needs to provide subscribers with movies they will love. Thus, the company promotes.
- Cinmatch: an automated system weekly analysis of cumulative films by using Pearson's correlation coefficient to all other movies to determine the list of "like" films that might appeal to users. It uses scores then calculates a multivariate regression, based on these correlations, based on the real-time online section of the system, to determine a unique, personalized prediction for each recommended film. If there is no personalized recommendation, the average score is used from all scores given to the film. These forecasts can be seen on the website through red stars.

D. Other Sub Approaches of Recommendation

1) Demographic recommendation: this approach uses demographic records such as age, gender, education, etc., to identify classes of users. This approach does not suffer from the new person problem because he does not use reviews to furnish recommendations. [1][18].

2) Recommendation based on knowledge [1]: This strategy takes the knowledge on products, such asfeatures and preferences explicitly requested by consumers.

3) Context-aware recommendation [19]: This approach generates more relevant recommendations through contextual information like time, location, and social data.

4) Recommendation based on psychological knowledge [1]: Recommendations based on psychological conditions like emotion, convincing, carefulness, presence, etc., can describe it.

III. Word2vec

A well-known word embedding algorithm is Word2evc [20]. It builds on two-layer neural networks to learn vector representations of the words composing the input text to represent close digital vectors for words that share similar contexts.

Word2Vec has two neural, CBOW and Skip-Gram architectures. The first receives a word context, i.e. the terms it entails in a sentence, as an input and tries to predict the word. The second word is used to indicate his context and to provide an input (see Fig. 2).

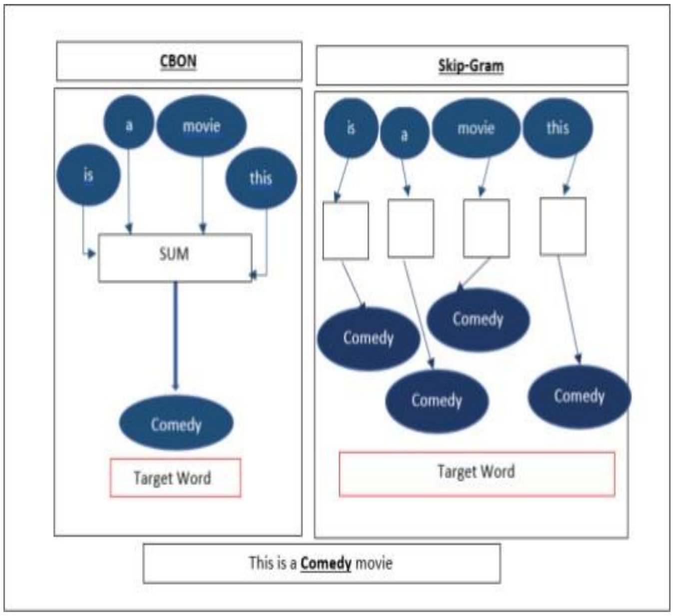

Fig. 2. CBOW and Skip-Gram Architectures of Word2vec Model.

IV. Explainable Artificial Intelligence

According to Lamy and al. [21], explainable artificial intelligence is an area that focuses on designing intelligent systems capable of explaining their outputs to humans, such as robots, artificial agents, planners, and machine learning algorithms. Several explanation methods and strategies, particularly for machine learning algorithms, have been proposed in the quest to make artificial intelligence systems explainable in a relatively short period. Methods of explaining are classified.[22] (see Fig. 3) in three categories:

1) The complexity of interpretability: The more complex the model is, the harder it is to interpret it. There is often a compromise between interpretability and accuracy. Therefore, we can classify explainable techniques in two ways according to the complexities of machine learning algorithms:

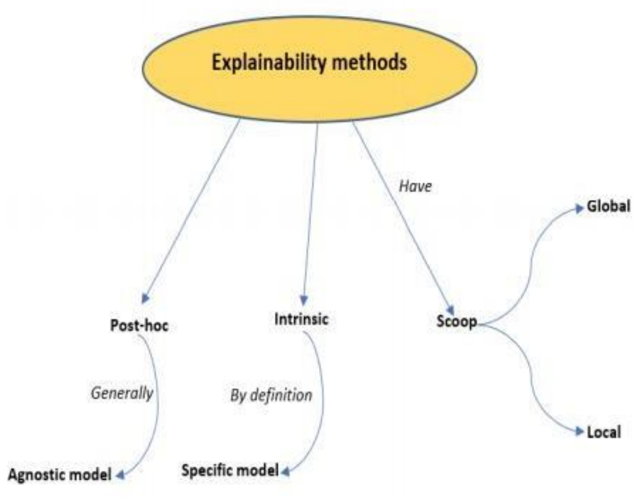

Fig. 3. Interpretable Machine Learning Methods.

a) An inherently and intrinsically interpretable algorithm (but less accurate), such as a decision tree.

b) Post hoc techniques consisting of a very highly complex and uninterpretable black- book model and use a separate set of strategies to complete a reverse technique to explain it without affecting or even knowing the inner part of the system.

2) The scoop of interpretability (local /global): these criteria help to define the perimeter of the interpretability of the model:

a) Global explainability: aims to make the decision-making process transparent for all data; this class of methods is valid when machine learning models are essential to inform decisions at the population level, such as consumption trends of drugs or climate change.

b) Local explainability: aims to provide explanations for a single decision in a restricted neighborhood of data, this class of interpretability methods is used to generate a particular explanation, in general, to justify the reason why the model made a decision specific, for instance. It should be noted that model-agnostic interpretations are generally post-hoc. Intrinsic methods are, by definition, techniques specific to a model.

3) Dependence level on the machine learning model used: Another meaningful way of classifying explanation model techniques is to determine whether they are:

a) Agnostic models: which means that they can be applied to any machine learning algorithm.

b) Specific models: which means that they can only be applied to a single type or algorithm class. The most popular methods of interpretation belong to the agnostic model.

Indeed, numerous model-agnostic methods, ranging from statistics, machine learning, and information science, have recently been developed. These are generally covered by four types [10]: Extraction of knowledge; Visualization; Methods of influence; Example explanations.

V. Related Work

This section suggests an analysis of the few existing explainable recommender systems in literature to detect axes of improvement. The current explainable recommendation is mainly divided into four general classes: (i) Matrix Factorization, Topic Modeling, (iii) Deep learning, and (iv) Graph Embedding models.

We analyze the essential works proposed in each class below. The Explicit Model Factor (EFM) is proposed by Zhang and al [23] to produce explicit recommendations, which aim to ensure high predictive accuracy. First, they analyze the feelings expressed in user reviews sentences and their explicit product characteristics comments. The approach suggested can provide personalized explanations alongside the recommendations, using the explicit features, such as: "We recommend the product because you are interested in a particular feature and this product is good functionality performance." By telling the user, the model can even give recommendations.

Bauman and al. [24] proposed the Sentiment Utility Logistics Model (SULM), which extracts characteristics and user sentiment on those characteristics. Features and sentiments are integrated into a factorization matrix to predict unknown sentiments and ratings, which are ultimately used to generate recommendations. The proposed method provides the recommended items to users and provides the recommended characteristics for an element, and these characteristics serve as explanations for a recommendation. For example, the method may recommend cinemas and important aspects over which the user has control and optionally select, such as the time to go to the movies.

Based on topic modeling class, McAuley and Leskovec [25] proposed to understand the hidden factors in the models of latent factors based on the hidden subjects extracted from textual reviews (reviews). To achieve this goal, the authors proposed the Hidden Factor and Subject Model (HFT), which links the latent factor models and the latent Dirichlet allocation (LDA) by linking each dimension of the latent item (or user) vector to each dimension of the subject distribution in LDA using a softmax function. In considering the information from the reviews, the proposed method improves the accuracy of predictions. Following this idea, Tan and al. [26] proposed to model the recommendation of elements and user preferences in a unified semantic space based on textual reviews. An item is built in as a recommendable distribution by topic in the modeling process, and the topics covered in these higher rating reviews are repeated to improve relevance. Likewise, a user is integrated into the same space, determined by their historical rating behaviors. The recommendation and preference distributions are finally integrated into the latent factorization framework to match the truth. The explanations for the recommended items are derived from the latent learned subjects.

Deep learning has gained much attention in the recommendation research community, and it has also been widely used for explainable recommendations [27]. Seo and al [28] proposed to model user preferences and element properties using convolutional neural networks (CNNs) during textual revisions with local and global dual focus when predicting notes from a user; the model selectively chooses the critical words with different attention weights, and with the learned attention weights the model can indicate which part of a review is more critical to the current prediction, in addition, the model can also highlight relevant words in comments as an explanation to help users understand the recommendations. Likewise, Wu and al. [31] merged user-article interaction and review information into a unified framework. User reviews are summarized carefully as content characteristics built into user/item embedding to predict final grades.

Based on graph embedding class, Ma and al. [29] proposed a new common learning framework to integrate the induction of explainable rules from a knowledge graph into the construction of a rule-driven neural recommendation model. The framework runs two modules to complement each other togenerate effective and explainable recommendations to have a better capacity for generalization to tackle the cold start problem because induced rules can supplement the recommendation module, especially as the circumstances of the same user can change over time, so this approach can achieve better results if authors integrate the axis of psychological recommendations. To create explanations, Ai and al. [30] suggested adopting knowledge graph embedding and designed a user-item knowledge graph; knowledge base embeddings are learned in the graph. The shortest way from the user to the recommended item can be explained via the knowledge graph.

By analyzing the approaches mentioned above, two glaring limitations emerge, existing explainable recommender systems are mainly based on comments written by users, which is not systematically available; indeed, users prefer to be served with minimum interaction with the system (users do not like comments) thus the lack of users comments and reviews impacts the quality of explainability of existing approaches. Second, the explanations provided are complex, unintuitive, and hard to understand by an average user (he needs the technical background to understand explanations).

VI. Proposed Approach

Inspired by existing explainable recommendation models, this approach aims to overcome explainable recommender system limitations.

1) Complexity of interpretations.
2) The necessity for textual user reviews.

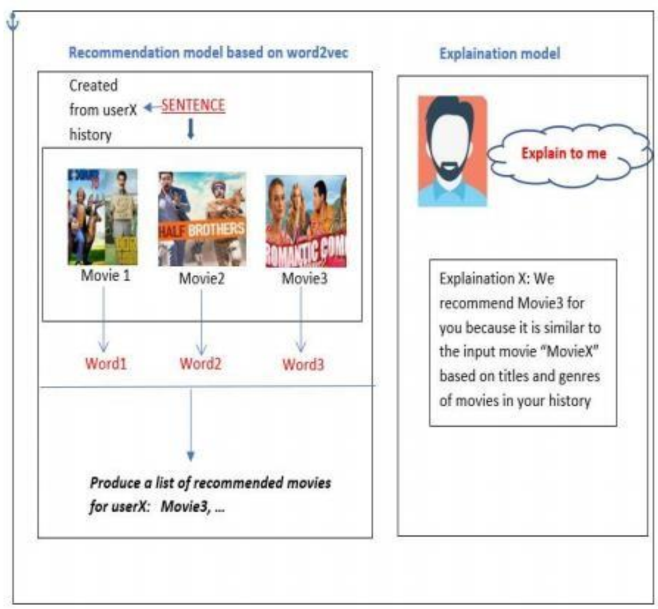

Fig. 4. An Overview of ExMrec2vec Approach.

We offer an embedded method of recommendation based on the word2vec algorithm. It is an ad-hoc model-agnostic; the explanation process is triggered after the recommendation process independently. Fig. 4 shows, through a simplified example (userX enters as input movieX), an overview of our explainable recommendation approach. The basic idea is to construct the vocabulary of the word2vec algorithm from the user history and generate recommendations for this user after training the word2vec model with the created vocabulary (see recommendation model based on word2vec in Fig. 4); then generate a simple explication for our average user. The word2vec model requires word and sentence equivalents, so we consider each movie as a word, and movies with similar user ratings are placed in the same sentence. To learn the movie embeddings to find relationships between movies to produce recommendations. We present a simple explanation for our lambda user; we will not show the details of embeddings learned from the word2vec model to an average user. We interpret recommended results generally; as we said, we try to overcome the limitation of complexity in the explanations in existing works in this field.

VII. Experiment and Evaluation

We used two available datasets to evaluate our proposition, MovieLens 20M Dataset, maintained by the MovieLens research team, will be used to evaluate our proposition. It has 20 million ratings and 465,000 tag applications from 138,000 users who have tagged 27,000 movies, and the latest movielens dataset contains 100,000 ratings applied to 9,000 distinctmovies by 600 users.

We used the "movies.csv" and "ratings.csv" files from the downloaded datasets. "movies.csv" is a lookup table for the movie's id and its name. "ratings.csv" contains the ratings of all the users for all the movies. We first separated the data into training and test sets. The test set is for the evaluation of the model. We used precision, recall, and F-1 score at K to evaluate our model performance.

Precision@k: The precision indicates the rate of relevant recommended items for all recommended items, the percentage of predictions we get right.

Recall@k: concerns the rate of relevant recommended items for all relevant items. The percentage of accurate labels captured when we recommend k labels per example.

F-1@k: is a combination of precision and recall. The F1 score takes values between 0 and 1. It turns 0 if one precision or recall is 0 and 1 if both precision and recall are 1.

To learn embeddings from our model, we need to have the equivalents of "word" and "sentence" from the downloaded datasets. Here we can consider that every "film" is a "word," Films with similar ratings are in the same sentence by a user. We considered all the movies "high rated" by a user to define the "meaning" for each movie. This process is applied to all the movies "low rated" by a user too.

Two models (for recommendation process) are trained with different parameters (see Table I and Table II):

TABLE I. PARAMETERS USED IN OUR IMPLEMENTATION

Parameters	**Meaning**
Number of epoch	Number of iterartions
Min_count	More than min_count times a filmmust be maintained to be keeped
Size	Size of the hidden layer
Workers	The number of threads for training
Sg	Sets the algorithm for training, weused skip-gram.
Hs	Negative sampling is used

TABLE II. PARAMETERS VALUES IN EACH MODEL

Parameters	**Model1**	**Model2**
Number of epoch	5	10
Min_count	10	5
Size	200	300
Workers	4	4
Sg	1	1
Hs	0	0

A set of recommendations is produced for each run on our proposition. The precision, recall, and F1-score of K can assess the performance of this task among the two defined models (K is the number of recommendations we made for each input).

In our implementation, precision indicated the rate of relevant recommended movies for all recommended movies, and recall indicated the rate of relevant movies for all relevant movies (movies high rated by user).

Note that the more movies a user has rated, the greater the accuracy and the lower the recall. On the other hand, the more recommendations made by our model (larger K), the lower the accuracy and the higher the recall, given the fixed number of "high rated" films. We constated these remarks when we interpreted precision and recall at K on a single model.

We extracted the "high rated" movies from both datasets and evaluated the precision, recall, and F1-score on both models we trained with different parameters are provided (see Table III and Table IV).

TABLE III. EVALUATION METRICS VALUES FROM MODEL 1 AND MODEL2 USING MOVIELENS 20M

Evaluation metrics	**Model1**	**Model2**
precesion@10	0.16	0.13
recall@10	0.07	0.059
F-1@10	0.095	0.08

TABLE IV. EVALUATION METRICS VALUES FROM MODEL 1 AND MODEL2 USING MOVIELENS LATEST

Evaluation metrics	**Model1**	**Model2**
precesion@10	0.15	0.13
recall@10	0.062	0.059
F-1@10	0.088	0.084

We constated from obtained results that model 1 is better than model 2 (with k =10, number of recommendation). So, ourrecommendation process will be based on module 1.

To demonstrate the effectiveness of our proposition, we compare our model ExMrec2vec with two traditional recommendation methods ("popular recommendation"," collaborative filtering"). based on the same evaluation metrics defined above (see Table V and Table VI) and using the two defined datasets.

TABLE V. COMPARISON RESULTS USING MOVIELENS LATEST

Evaluation metrics	ExMrec2vec	Popular model	Collaborative model
precesion@10	0.15	0.12	0.14
recall@10	0.062	0.053	0.05
F-1@10	0.088	0.077	0.081

TABLE VI. COMPARISON RESULTS USING MOVIELENS 20M

Evaluation metrics	ExMrec2vec	Popular model	Collaborative model
precesion@10	0.16	0.13	0.12
recall@10	0.07	0.066	0.069
F-1@10	0.095	0.072	0.073

Popular model: A common standard approach basically prescribes the foremost prevalent items that the user has not already devoured.

Collaborative model: This approach employments the memory of past users intuitive to compute users' similitudes based on items they've connecting (user-based approach) or compute items likenesses based on the clients that have connected with them (item-based approach). We used the time-based approach.

Obtained results (see Table V and Table VI) prove the effectiveness of our proposed model. (We plan to compare another advanced version of our model with other complicated algorithms in the future).

We implemented the user interaction scenarios with the recommendation explanation interfaces. Since we used the movielens datasets, we then positioned ourselves in the context of an online movie recommendation system called "ExMRec2vec". Typically, each user of the "ExMRec2vec" site will connect using his "login" and his password "password."

Take the example of the user "U17" who will connect (Fig. 5).

After logging in, the user enters a movie as input to search (see Fig. 6).

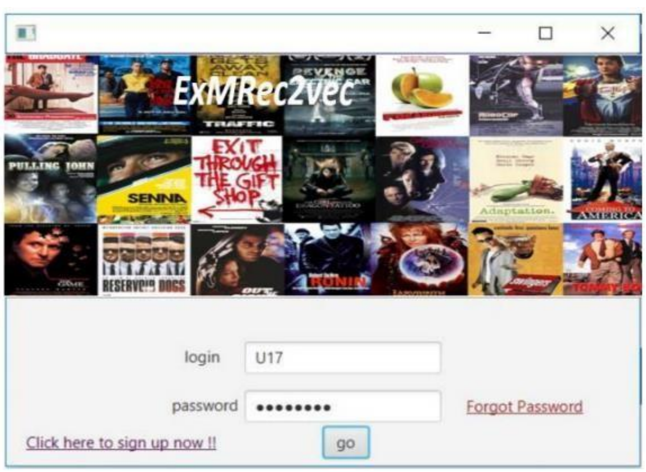

Fig. 5. Connection of User "U17".

Fig. 6. The Interface that Offers the Search for a Movie Entered by the Active user "U17".

Our U17 user has "Ratatouille (2007)" as a recommended movie to him. If he wants to know any explanations for this recommendation, once he clicks on "why" he will automatically have the reason available which explain this recommendation (see Fig. 7).

Fig. 7. The Interface of Recommendation and Explanation.

VIII. Conclusion

In this article, we proposed a movie recommendation approach that allows improving the performance of movie recommender systems by accompanying recommended movies with simple explanations. Which increases recommender systems acceptance and makes them applicable to an even broader range of applications (not only for movies). The proposed approach is based on the word2vec model via using the history of users to produce recommendations, then presenting simple explanations through the input movie.

The conducted experiments on different parameters prove the quality of model 1, see Section VII, we demonstrate the effectiveness of our proposed model Exmrec2vec by conducting a comparison between our model and two traditional models.

We plan to enhance encoded word2vec vocabulary by introducing other social relations based on learned similarity using different machine learning algorithms and improving movie-movie relationships using the complementarity concept.

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Using Blockchain in the Internet of Things Coordination

A Smart Contract-based Approach

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***Abstract*—Now-a-days, the Internet of Things (IoT) has generated enormous interest from industry to create distributed and innovative solutions. However, achieving this goal is a tedious task and presents several open challenges as the literature points out. One of the most complex is the IoT coordination service. Unfortunately, most research works give rarely importance to this service in their models or architectures proposals. Wherefore our current contribution deals with this open issue and proposes a solution capable of implementing advanced processes that can be based on orchestration, choreography or both mechanisms. More over and to conduct efficiently both coordination mechanisms when sharing knowledge or tasks between connected objects, we integrate smart contacts to guarantee the modalities of behavior change in the coordination mechanism. Smart contracts are a safe way to decide the coordination mechanism based on the state of the system environment. To prove our approach, we have built a technical architecture based on a multi-agent system to abstract connected objects of IoT systems, blockchain technology, and the frameworks and languages required for collaboration processes such as BPMN, BPEL and BPEL4CHOR. Carbon leakage as a case study is used for experimentation.**

Keywords*—Internet of things; IoT; Internet of things coordination; blockchain; smart contract; multi-agent systems

I. Introduction

Internet of things (IoT) defines a network of dedicated physical objects (things) that contain embedded technology to communicate and sense or interact with their internal states or the external environment. Based on such technology the connecting of assets and processes enables the capture of data and events from which an organization can learn behavior and usage, react with preventive action, or augment or transform business processes. Consequently, IoT provides a foundational capability for the creation of a new digital business [1].

However, the development of IoT has encountered challenges that are necessary to meet. Among these challenges, coordination represents the core of any IoT system as it consists of organizing things, objects, information, tasks, functionalities, services, in order to enable them to work together efficiently to attain a required and desired objective. Furthermore, other challenges are unfortunately closely linked to coordination, which makes its achievement more complex. One of the major obstacles facing IoT coordination is the lack of flexible architecture, and that motivates us to propose our vision to build a suitable architecture [2].

Coordination needs an entire organization to be handled, as it requires understanding and following the building blocks of IoT: identification, data acquisition, data processing, interpretation/semantics, and decision-making. This has guided us towards a system that requires good management of connected objects, and infrastructure to manage data: storage, processing, and analysis, which will lead to appropriate decision-making.

In this paper, we present an architecture based on multi-agent system (MAS) and smart contracts for coordination processes. This architecture consists of three main layers: meta-workflow layer, coordination layer, and object layer. The meta-workflow represents the business part where the main workflow is modeled using BPMN. The coordination layer is made up of three sub-layers: agent abstraction, data management, and coordination mechanism. The agent abstraction sub-layer represents agents that abstract physical objects. As coordination consists in organizing the cooperation of connected objects by sharing knowledge, MAS is most suitable to achieve this purpose as agents rely on each individual's capacities and knowledge. The coordination mechanism sub-layer defines the description of the mechanisms, namely orchestration and choreography is to take on. The data management sub-layer counts the system's policies on gathered data and the smart contracts. Policies are the rules that make it possible to decide on the coordination mechanism according to conditions through the data gathered from the environment. Smart contracts make it possible to ensure coordination mechanisms used and define the actions to undertake.

Generally, coordination is approached from the point of view of services. The actions and interactions of objects are broken down into several independent services. Service-oriented architecture (SOA) has been integrated to achieve this. However, SOA has limitations regarding dynamic multi-service collaboration especially when the collaboration is triggered by complex events [3].

These limitations also affect the ability to adapt to changing business requirements, to the resolution of flexible and distributed collaboration, to the coordination of real-time interaction and collaboration between multiple agents [4].

IoT represents networks formed on a distributed architecture connected objects in which resources are not stored on a central node. These connected objects collaborate and coordinate their behavior [5] even if they have only limited knowledge of their environment or other objects on the network to achieve the system's goal. Coordination mechanisms can change based on coordination policies that allow objects the ability to decide on the coordination mechanism to use.

Since coordination service manages the behavior of IoT systems through the sharing of data and knowledge, the execution of tasks, etc. between its components, it becomes essential to conduct efficiently the behavior state of the whole IoT systems by supervising the execution of coordination mechanisms. Wherefore we have focused on integrating blockchain technology by using smart contracts with coordination policies due to its benefits in various fields. Blockchain is a technology that enables autonomous operation driven by rational decisions over participants. This ability to organize the flow of interactions reliable between -unknown-participants makes the blockchain a powerful instrument for coordination [6]. It decentralizes trust in a consensual manner, through peer interactions, and strengthens coordination. With the technology of smart contracts, objects can coordinate their behaviors to approve or reject changes in the coordination mechanism. Smart contracts stored on blockchains are self-executing contractual states that are not controlled by anybody, so they can be trusted. This can improve the impartiality and efficiency of policy management.

Blockchain, therefore, comes with the solution to the limitations of traditional coordination among IoT objects.

In our approach, smart contracts take a part in the coordination process as they define the coordination mechanism and the actions to undertake according to the environment's changes that agents take awareness of.

The remainder of the paper is structured as follows: Section 2 presents the related work along with a discussion according to the coordination process. Section 3 introduces our proposed IoT coordination architecture, whereas Section 4 highlights its behavior. Section 5 describes carbon leakage as a case study for experimentation. Section 6 presents the technical architecture used for the approach’s implementation. Section 7 exposes the conclusion and future work.

II. Related Work

The paper [7] presents a large-scale blockchain-based storage system, called Sapphire for data analytics in the internet of things. In the paper, authors have pointed out that autonomous coordination is required in a decentralized IoT solution, and the different IoT devices that interact with each other have varying levels of trust depending on the rules of engagement that they are operating via constraints. IoT devices are equipped with smart contracts that achieve contractual agreements with other devices. However, the use of smart contracts for the coordination of objects and their organization in the distributed network does not focus on the coordination in itself but its main goal is to achieve operational security.

An architecture for managing heterogeneous IoT is presented in [8]. It is mentioned that blockchain enables decentralized coordination to overcome IoT inherent challenges. The system is implemented in layers 3, 4 and 5 of the IoTWF reference model. The architecture adopts a hierarchical design that consists of having much core IoT participating in a public blockchain and used to realize monitoring, roll-backs, achieve coordination, and exchange data. The achievement of coordination is not further explained in the paper even though authors supported the importance of blockchain in the decentralized coordination of connected objects.

The paper [9] presents the importance of integrating IoT and Blockchain into the processes of a university campus. They started by introducing the three general architectural models of the three concepts: the university's network architecture, IoT, and distributed blockchain. Then, they established the university campus' architecture integrated with IoT to identify the security weaknesses of the IoT. And finally, they displayed where the integration of blockchain can handle the vulnerabilities and perform all the security needs an IoT system requires. In the paper, it is mentioned that the blockchain layer allows coordination between the different devices but does not shed more light on how the coordination has been approached.

In [10], an architecture pattern for trusted orchestration management is presented. The authors presented the behavioral and structural properties of the architecture pattern. They started by introducing the trusted orchestration management principles and requirements based only on security. The actions for this trusted orchestration management is the deployment and execution of the components along with the logging and identity management of all orchestration-related actions. Here, the authors included blockchain to manage security and smart contracts to define orchestration decisions. The use of blockchain and smart contracts in this paper was only from a security (identity, origin, non-repudiation) point of view to ensure trust.

Authors in [11] considered the integration of IoT, blockchain, and Building Information Modeling for the design of a smart building as the safety of people, security of data, and efficiency of construction are keys to smart building foundations. In this paper, it was highlighted that integration of blockchain and IoT with Building Information Modeling (BIM) is a great way of overcoming data sharing between IoT objects and managing data, but they didn’t give further details as they focused only on security issues.

An IoT-Blockchain fusion model is presented in [12]. It integrates four layers: perceptual layer, network layer, blockchain layer, and application layer. Smart contracts are responsible for realizing transactions among the device. They are built on the blockchain which provides security and takes on the IoT data storage along with external distributed storage solutions. The devices' interactions and exchange of information are not mentioned in the paper. The use of blockchain was mainly for its trustful infrastructure.

In [13], a decentralized trust framework, called IoT Passport, for collaborative IoT based on blockchain technology is presented. It is composed of three layers: the Perception Layer, the Network Layer, and the Application Layer. Smart contracts are used to program common rules used to issue passports to each device, in addition to other rules about collaboration, authorization attributes, rewards, etc. Blockchain is used for its trust mechanisms and access control approaches.

III. Discussion

The integration of blockchain with IoT is gaining momentum in research. However, in the works presented, this integration essentially presents only the security aspect and does not display the importance of integrating blockchain for coordination. In a matter of fact, blockchain cannot be used only for purposes namely security, trust, value transfer, but effectively for coordination… Coordination is a complex challenge that is linked to several others. In previous work, we established that to achieve coordination, we must take into account other challenges related to it namely discovery, heterogeneity, availability, context-awareness, decision-making [2], and which allows respecting the coordination process identification => data acquisition => data processing => Interpretation => decision-making [14].

1) Identification: gives a clear and unique identity to each device in the system. There are different identifying methods like EPC (electronic product codes), uCode, an identification number system. Addressing also can assist to uniquely identify objects within the network. It includes IPv4 and IPv6/6LoWPAN.

2) Data acquisition: means gathering data (sensing) from objects in the network. These objects can be sensors or actuators.

3) Data processing: when data is gathered from the devices, it needs to be processed. There are different methods of processing like classification, storing, calculation, etc. that are used to extract meaningful information from the data.

4) Interpretation: Information issued from data processing needs to be interpreted to facilitate decision-making. This interpretation can be done through different methods: policies, cloud-based analysis, machine learning technics, deep learning, neural networks, etc.

5) Decision-making: The support of appropriate decision-making is the interpretation phase. Decision-making dwells on the turn that the system can take through the actions to be taken. It is the result of extracting knowledge from interpreted information.

Table I presents the classification of related work according to the coordination process.

Due to blockchain's distributed aspect and with the use of multi-agents, coordination can be established despite all the challenges and issues linked to it. Indeed, sharing information and data is more accessible and cooperation among different parties is enabled and with the use of smart contracts, participants' behaviors are coordinated. This motivated us to propose an IoT architecture that integrates blockchain. It is presented in the following sections.

TABLE I. IoT Coordination Process Classification

	Quanqing X. et al (2018)	**Tseng L. et al (2020)**	**Villegas-Ch W. (2020)**	**Pahl C. et al (2018)**	**Lokshina I.V. et al (2019)**	**Gong X. et al (2020)**	**Tang B. et al (2019)**
Identification	-	Private blockchain	-	Devices register to a local network	-	Unique address in the blockchain	IoT passport
Data Acquisition	Smart cities, smart grid, smart home, smart building	IoT devices	IoT devices	IoT devices	Smart building	Smart devices	IoT devices
Data processing	Data classification, custom processing	Analytics procedures in the cloud	Big data layer	cloud	-	Network layer	-
Interpretation	-	-	Big data layer	cloud	-	-	-
Decision-making	-	-	-	-	BIM	-	-

IV. IoT Coordination Architecture

The following architecture is defined in agreement with the coordination process already presented. It consists of three layers described in the following and it is depicted in Fig. 1.

1) Meta-workflow layer: This layer holds the meta-workflow. It represents the static modeling of the global process which, in a common environment, pursues a normal execution.

2) Coordination layer

This layer represents the key of our architecture. It includes the following components:

- Policies: representing rules that will disrupt the behavior of the system. They are classified into two categories: environmental policies, which represent conditions on the data collected from the environment, and coordination policies which are established according to environmental policies and which determine the coordination mechanism to be adopted.
- Agent abstraction: Connected objects are abstracted using MAS. Each abstracting agent has access to the abstracted object components (i.e sensing and actuating components, computation, communication, and storage components). Thus, the sensed data are processed at this level to extract needed information. The choice to use agents at this level was decided as coordination falls under the distributed resolution of problems which consists in organizing the cooperation of connected objects by relying on each individual's capacities and sharing knowledge.

Agents are defined by their roles (or actions) and their knowledge of the environment.

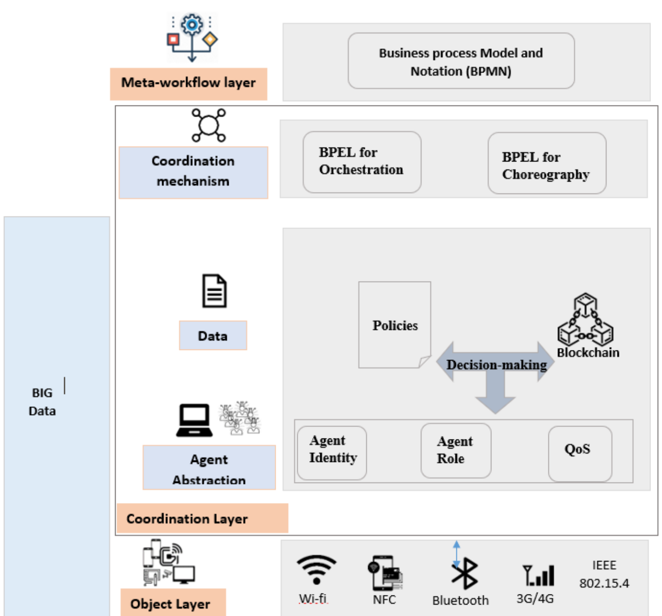

Fig. 1. Proposed Architecture.

Knowledge of the environment is the part of the environment's general states that the agent knows about. It takes into consideration one or several environmental policies.

Roles are the actions that the agent takes when operating:

- Data-collection: the agent interrogates its environment for collecting data.
- Data-storage: the agent stores information or collected data.
- Data-processing: The agent processes the collected data to extract information.
- Data-interpretation: interpretation of processed data.

- Data:

a) Data storage: During system operation, data is collected and stored for the purpose of analysis and monitoring in real-time.

b) Blockchain: Smart contracts: smart contracts group together the terms and conditions for the change of the coordination mechanism and also the agents involved in the coordination and who consent to that change.

Depending on the policies, the behavior of the system may change. The contract checks that everything is in order according to the environment and decides on which action(s) to undertake. Every call to the contract is a transaction saved on the blockchain.

- Coordination mechanisms: orchestration and choreography represent the coordination mechanisms that are used mostly. Usually, either orchestration or choreography is used as a coordinating mechanism. The goal is to combine the advantages of both to better manage the cooperation of objects in performing actions, especially critical ones.

CASE1: Orchestration: the whole organization is managed from the point of view of a single agent. The agent chosen to orchestrate the application's operation is the agent that acts as the system's environment (agent coupled with an actuator).

CASE2: Choreography: the organization is managed from a global perspective. Each agent is responsible for their behavior and works together with other agents to fulfill the overall goal of the application.

CASE3: Switch between orchestration and choreography: in this case, during the operation of the system, the coordination mechanism can change and switch from orchestration to choreography and vice versa depending on the agent's policies and coordination policies, according to the smart contracts.

CASE4: Both orchestration and choreography: throughout the system's operating, one or several agents can be engaged in choreography while at the same time their actions are orchestrated. Both mechanisms are used in parallel and the agent(s) enrolled have different tasks to manage.

3) Object layer: The object layer represents the various connected objects of the system. Different connection modes can be used, namely Wi-fi, Bluetooth, 3G/4G, NFC.

An object has its own mechanical and/or electrical function. For its connectivity either, the object is directly designed connectable or it exists already and the connectivity is added afterward.

These objects perform functionalities like querying their environment and collecting sensor data (sensors) and/or receive instructions to act (actuators). These functionalities require a source of energy that represents one of the great challenges of connected objects, both to guarantee the longest possible service performance without maintenance, and to guarantee environmental respect despite the proliferation of energy-intensive connected objects.

Physical objects are abstracted into agents. This abstraction is done through the description of these objects. Each of them has properties that can be described.

4) Big data: This module is an important part of any IoT system. It enables us to process a large amount of data on a real-time basis and storing them using different storage technologies. It helps to improve decision-making by analyzing gathered data on the system and the environment. For now, we didn't focus on this part as there are several solutions to data analysis for IoT. We believe we have to mention this part as it represents an important element of the development of any IoT system and we will go into details about this subject in our future work.

V. Architecture's Behavior

A. *Meta-Workflow Layer*

A meta-workflow designates a high-level process that defines the overall execution of the system or application, including the tasks to be performed in a normal environment and the overall objective to be achieved by the system are identified. The meta-workflow is defined in BMPN. Then, the workflow modeled in BPMN is translated into BPEL. This transformation makes it possible to have an executable process.

As the coordination has two mechanisms, orchestration and choreography, the BPEL makes it possible to describe both. Depending on the meta-workflow, the use cases for orchestration or choreography are written in BPEL and BPEL4CHOR.

B. *Coordination*

In its normal functioning, the coordination mechanism is set on either of the cases presented before. When the system encounters a delicate or critical case, depending on established policies, the coordination mechanism may change. This change and the actions that follow result from the call to the smart contract which represents the transactions that are stored on the blockchain. Agents communicate with each other using MQTT. Some require data from other agents to continue their work or provide services. At the slightest change in the environment that requires special attention, the agent or agents that handle the situation inform the coordinated agents to confirm the change of the coordination mechanism following the smart contracts. They ensure that the conditions of the coordination policies are verified and then the transaction is done.

C. *Policies*

Coordination actors can be numerous and the existence of constraints limits the extension of the scope of coordination. Determining the coordination changes is necessary for the proper functioning of the system because, without a meticulous definition, coordination can conflict with the specific objectives of the objects. This is where the coordination policies come into force. They define the changes in the coordination mechanism through conditions that are evaluated from the data collected by connected objects.

D. *Smart Contracts*

Smart contracts are the system that will ensure the terms and conditions of the change in the coordination mechanism. For a given application, the contract guarantees that the coordination policies are respected for the two coordination mechanisms. It provides, based on environment data the coordination mechanism to apply and the actions to undertake under the change that has occurred.

E. *Operating Coordination Algorithms*

Operating algorithms for the Orchestration process and Choreography process are shown in Fig. 2 and Fig. 3.

In the case of an Orchestration

1. Orchestrator loads the smart contract
2. Orchestrator calls remotely the smart contract's methods through its instance

2.1. The Contract's method:

  2.1.1. Evaluates the alert

  2.1.2. returns the result on the coordination mechanism and the action(s) to undertake

  2.1.3. IF the coordination mechanism changes:

    2.1.3.1. Orchestrator informs the coordinated agents

    2.1.3.2. Do choreography algorithm

  2.1.4. Else Continue on Orchestration algorithm

Fig. 2. Coordination Algorithm in Case of Orchestration.

In the case of a choreography

1. For each x in $\{j, k, \ldots, p\}$

  1.1. Agent A_x loads the smart contract

    1.1.1. A_x calls remotely the smart contract's method through its instance

    1.1.2. Contract's method:

      1.1.2.1. Evaluates the alert

      1.1.2.2 Returns the result on the coordination mechanism and the action(s) to undertake

    1.1.3. IF the coordination mechanism changes:

      Do Orchestration algorithm

    1.1.4. Else Continue on Choreography algorithm

Fig. 3. Coordination Algorithm in Case of Choreography.

VI. Use Case Study

Smart home devices operate together, automating actions and sharing consumer data. This provides homeowners convenience, comfort, and energy efficiency. These functions require coordination among devices, thus the smart home was chosen to explain more the operating of our architecture. From the smart home use case, the application of a carbon leak is chosen to illustrate the functioning of the architecture.

We have three agents: CarbonAgent that senses the level of the carbon rate in the environment; oxygenAgent senses the oxygen rate in the environment; windowAgent that acts on the environment (action of opening or closing).

When the operating coordination mechanism is orchestration, the agent windowAgent is the orchestrator. The choice was made as it listens to events emitted by the other agents that capture environmental data and acts based on them. The operating of the application is as follows:

1) Carbon Agent

```
1- CarbonAgent.getCarbonValue()
      CarbonAgent.Save(CarbonAgent.getCarbonValue())
2- CarbonAgent.getCarbonPolicy()
3-if
(CarbonAgent.getCarbonValue().comparteTo(CarbonAgent.ge
tCarbonPolicy) ==1)
      CarbonAgent.Send(Alert)
4-if CarbonAgent.receive(decision)
      CarbonAgent.doDecisionAction()
  else Continue
```

2) Oxygen Agent

```
1- OxygenAgent.getOxygenValue()
      OxygenAgent.Save(OxygenAgent.getOxygenValue())
2- OxygenAgent.getOxygenPolicy()
3-if
(OxygenAgent.getOxygenValue().comparteTo(OxygenAgent.g
etOxygenPolicy) ==1)
      OxygenAgent.Send(Alert)
4-if OxygenAgent.receive(decision)
      OxygenAgent.doDecisionAction()
  else Continue
```

3) Window Agent

```
1-String address=WindowAgent.DeployContract(credentials)
2-Contract contract =
WindowAgent.LoadContract(address, credentials)
3-if (Receive
(CarbonAgent.Alert|| OxgenAgent.Alert))
  contract.Method()
  WindowAgent.receiveDecision()
  WindowAgent.send(decision)
  WindowAgent.doDecisionAction()
   else
      WindowAgent.close()
```

When choreography is of use in the scenario, the operating algorithm for each agent is as follows:

1) Carbon Agent

```
1-String address =
CarbonAgent.DeployContract(credentials)
2-Contract contract =
 CarbonAgent.LoadContract(address, credentials)
3- CarbonAgent.getCarbonValue()
4-CarbonAgent.getCarbonPolicy()
5-if
(CarbonAgent.getCarbonValue().comparteTo(CarbonAgent.ge
tCarbonPolicy) ==1)
  contract.Method()
  CarbonAgent.receiveDecision()
  case1:
  CarbonAgent.send(Alert) to WindowAgent
  case2:
  Keep sensing (CarbonAgent.getCarbonValue())
```

2) Oxygen Agent

```
1-String address=
OxygenAgent.DeployContract(credentials)
2-Contract contract=
OxygenAgent.LoadContract(address, credentials)
3- OxygenAgent.getOxygenValue()
4-OxygenAgent.getOxygenPolicy()
5-if
(OxygenAgent.getOxygenValue().comparteTo(OxygenAgent.g
etOxygenPolicy) ==1)
   contract.Method()
   case1:
    OxygenAgent.send(Alert) to WindowAgent
   case2:
    Keep sensing (OxygenAgent.getOxygenValue())
```

3) Window Agent

```
1-String address=
     WindowAgent.DeployContract(credentials)
2-Contract contract =
 WindowAgent.LoadContract(address, credentials)
3-if
(Receive(CarbonAgent.alert || OxygenAgent.alert ))
   WindowAgent.open()
 else
   WindowAgent.close()
contract.Method()
WindowAgent.receiveDecision()
```

Here are the operating for each orchestration and choreography approach to coordination. Based on the data gathered from the environment, the smart contract decides which scenario to apply. The different cases that could be encountered are those presented in Section 3, coordination mechanisms.

VII. Technical Architecture

This section presents the technical architecture that highlights the technologies used to implement the approach. It is depicted in Fig. 4.

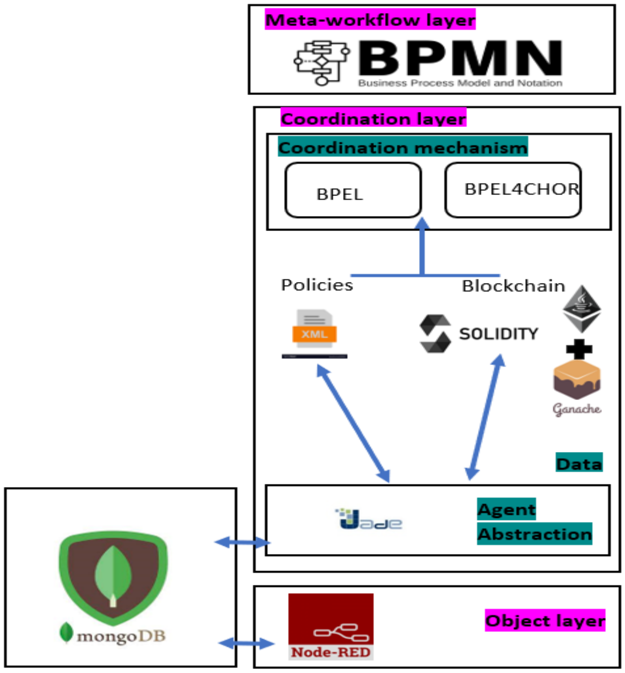

Fig. 4. Technical Architecture

A. Technologies of Implementation

1) Meta-workflow: BPMN: Business Process Model and Notation, is a business process modeling method to describe the value chains and business activities n the form of of a graphic representation.

2) Coordination:

- Mechanism: Translation BPMN to BPEL/ BPEL4CHOR. There are several solutions to transform BPMN into BPEL in the literature namely Oracle Business Process Analysis Suite/Oracle Business Process Management Suite; VIATRA2; graph transformation.
- Policies: XML.
- Smart Contracts: solidity. The contract written in solidity is compiled using solc which generates bin and abi files, and then, a java version of the contract is generated using web3j through the bin and abi files.
- Blockchain: ganache. It is a tool that enables you to set up a personal ethereum blockchain. All transactions are viewed and tracked there.
- Agent abstraction: Agents are developed in JADE (Java Agent Development Framework). The communication between agents is based on events and handled through MQTT. For this implementation, HiveMQ cloud is used.

3) Objects: Smart objects are handled using Node-red. Their profiles are stored in a mongo Data Base.

4) Big data: In addition to the objects' profiles, mongoDB is used to save data that agents gather from the environment for further analysis.

B. Description of the Implementation

This paragraph shows some implementation screenshots.

At the meta-workflow level, the functioning of the system is modeled with BPMN as shown in Fig. 5 and Fig. 6. Visually depicting system processes helps link the intent of the process to its implementation while serving to improve efficiency and accommodate new circumstances. BPMN, therefore, allows a better understanding of all the steps of a business process to achieve a more efficient process producing a quality result.

One of the advantages of BPMN is that it leads to the creation of documents in XML which are fundamental to the execution of the process, especially in BPEL. In BPEL, individual activities are called Partner Link exposed as web services that can be used by other BPEL processes. BPEL provides basic activities and functions as well as the exception and transaction handling, also to model control flow between activities there are structured elements such as loops or conditional commands.

Fig. 7 shows an example of the used BPEL code to describe an orchestration business process, whereas Fig. 8 displays an example of code to describe a choreography process.

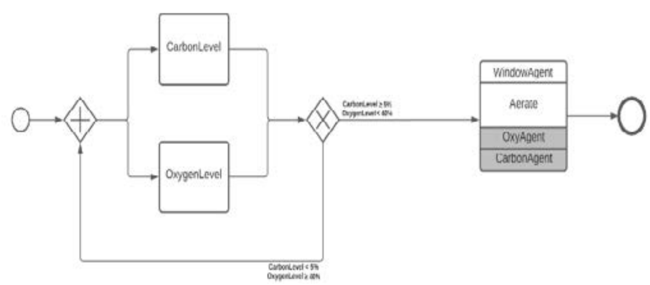

Fig. 5. Meta-Workflow in BPMN.

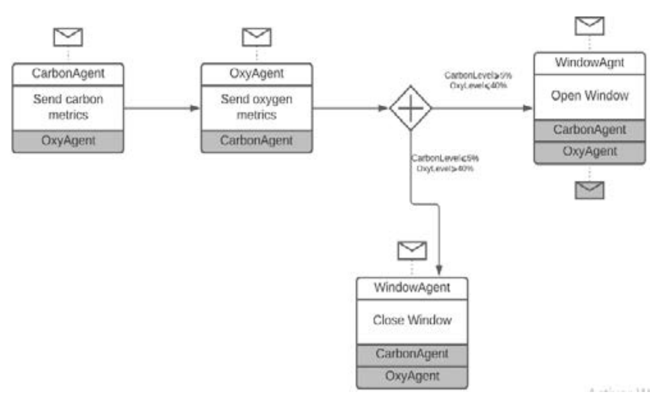

Fig. 6. Detail of the Choreography.

```xml
<sequence>
  <invoque name="CarbonLevel"/>
  <invoque name="OxygenLevel"/>
  <if>
    <condition> bpws:getCarbonPolicy &lt; $inputC.payload</condition>
    <invoke name="SendNotification"/>
    <receive name="receiveCarbonLevel" partnerLink="CarbonAgent" portType="tns:Home"
    operation="process" variable="AlertCL" createInstance="yes"/>
    <invoke name="ChangeMecanism" partnerLink="WindowAgent" operation="CallContract" inputVariable="Alert" outputVariable="Decision"/>
  <else>
      <invoke name="Normal"/>
  </else>
  </if>
  <if>
    <condition> bpws:getOxygenPolicy &lt; $inputT.payload</condition>
    <invoke name="SendNotification"/>
    <receive name="receiveOxygenLevel" partnerLink="OxygenAgent" portType="tns:Home"
    operation="process" variable="AlertOL" createInstance="yes"/>
    <invoke name="ChangeMecanism" partnerLink="WindowAgent" operation="CallContract" inputVariable="Alert" outputVariable="Decision"/>

  <else>
    <invoke name="Normal"/>
  </else>
  </if>
</sequence>
```

Fig. 7. BPEL for Orchestration Process.

```xml
<participantTypes>
    <participantType name="CarbonAgent" participantBehaviorDescription="carbonAgent:carbonAgent" />
    <participantType name="OxygenAgent" participantBehaviorDescription="oxygenAgent:oxygenAgent" />
    <participantType name="WindowAgent" participantBehaviorDescription="windowAgent:windowAgent" />
</participantTypes>
<participants>
    <participant name="carbonAgent" type="CarbonAgent" />
    <participant name="oxygenAgent" type="OxygenAgent"/>
    <participant name="windowAgent" type="WindowAgent"/>
    <participantSet name="aerate" type="Aerate"
    forEach="CarbonAgent:RequestAerate">
        <participant name="windowAgent"
        forEach="carbonAgent:RequestOpen" />
    </participantSet>
    <participantSet name="aerate" type="Aerate"
    forEach="OxygenAgent:RequestAerate">
        <participant name="windowAgent"
        forEach="oxygenAgent:RequestOpen" />
    </participantSet>
</participants>
```

Fig. 8. BPEL4CHOR for Choreography Process.

Coordination policies are written in XML as shown in the Fig. 9. The document is structured and the information is simple and efficient.

```xml
<rule name="asphyxia">

    <condition namechild="CarbonValueMax">
            <conditionvalue id= "val" name2="carbonLevel" maxval="5"/>
    </condition>

</rule>
```

Fig. 9. Coordination Policy.

Smart contracts are written in Solidity as shown in Fig. 10. Solidity is the programming language in which Ethereum smart contracts are based.

To make remote calls of the contracts between agents, a java code version of the contract is generated using Web3j as described in the Fig. 11.

```solidity
pragma solidity ^0.8.5;

contract CarbonContract {



    function actions (string calldata state)  public pure returns(string[2] memory) {

        string[2] memory decision=["Continue","Orchestration"];
        if(keccak256( abi.encodePacked(state)) == keccak256( abi.encodePacked("AlertCarbon"))
           || keccak256( abi.encodePacked(state)) == keccak256( abi.encodePacked("AlertOxygen"))){

            decision[0]="OpenWindow";
            decision[1]="Choreography";
            return (decision);
        }
        else {
            return (decision);
        }
    }
}
```

Fig. 10. Smart Contract in Solidity.

```java
package solidityGen;

import java.math.BigInteger;
import java.util.Arrays;
import java.util.Collections;
import org.web3j.abi.TypeReference;
import org.web3j.abi.datatypes.Function;
import org.web3j.abi.datatypes.Type;
import org.web3j.crypto.Credentials;
import org.web3j.protocol.Web3j;
import org.web3j.protocol.core.RemoteCall;
import org.web3j.protocol.core.methods.response.TransactionReceipt;
import org.web3j.tx.Contract;
import org.web3j.tx.TransactionManager;
import org.web3j.tx.gas.ContractGasProvider;

/**
 * <p>Auto generated code.
 * <p><strong>Do not modify!</strong>
 * <p>Please use the <a href="https://docs.web3j.io/command_line.html">web3j command line tools</a>,
 * or the org.web3j.codegen.SolidityFunctionWrapperGenerator in the
 * <a href="https://github.com/web3j/web3j/tree/master/codegen">codegen module</a> to update.
 *
 * <p>Generated with web3j version 3.6.0.
 */
public class CarbonContract extends Contract {
    private static final String BINARY = "608060405234801561001057600080fd5b50...

    public static final String FUNC_ACTIONS = "actions";

    @Deprecated
    protected CarbonContract(String contractAddress, Web3j web3j, Credentials credentials, BigInteger gasPrice, BigInteger gasLim
```

Fig. 11. Java Version of the Smart Contract.

Each remote call to the smart contract is a transaction. Agents call the deploy and load methods of the contract generated by web3j to instantiate it. Then the instance of the contract is used to call other methods of the contract whenever needed.

Transactions are stored in the blockchain. We used Ganache to visualize these transactions as shown in Fig. 12.

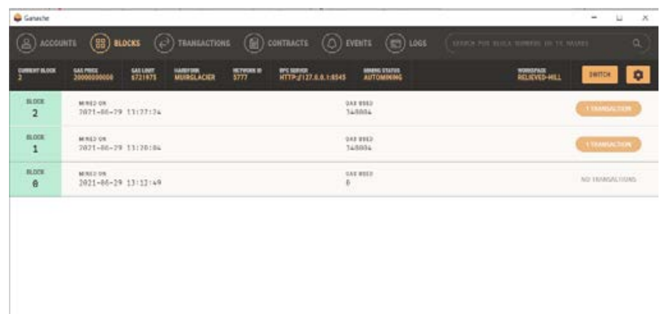

Fig. 12. Blocks in Ganache.

VIII. Conclusion

In this paper, we have studied the possibility of using blockchain in the IoT coordination process. We proposed an approach that complies with IoT coordination process requirements namely identification- data acquisition- data processing- interpretation and decision-making. This approach uses multi-agent system to abstract IoT objects, smart contracts to regulate the coordination mechanisms to be handled, and actions that follow each change in applied orchestration or choreography mechanisms. To prove the effectiveness of our approach, we first built a technical architecture of our proposed IoT coordination architecture based on multi-agent systems modeling, blockchain technology and the frameworks required for IoT coordination. Then we experimented with carbon leakage as an application of a smart home use case.

As results our proposed approach allowed to support coordination requirements securely and transparently, by using blockchain as a distributed platform reinforcing coordination. This finding allowed us to work on challenging fields such as urban traffic control and agritech applications to enhance our proposed framework.

We plan as a future work to focus on scalability problem resolution, and the use of big data benefits to optimize the decision-making on the coordination mechanisms.

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Improving Data Security using Compression Integrated Pixel Interchange Model with Efficient Encryption Technique

Compression Integrated Pixel Interchange Model

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***Abstract*—We exist in a digital era in which communication is largely based on the transfer of digital knowledge over data networks. Disclosures are sometimes regarded as a transmitter that transmits a digital file. A system of encoding, efficient and easy yet secure model must be developed for quick and prompt transmission. The file is sent from source to destination where it is difficult to maintain the privacy of knowledge. The encryption of images is vital for securing sensitive information or images from unauthorized readers. By using a technique of selective encryption, the original image pixel values are completely obscured in this way and an intruder cannot retrieve statistical data from its original image. This paper introduces a new methodology for the use of a protective facility for the transmission of digital data over the public network. A highly established field with image compression is allowed for speedy transmission and efficient information storage. During the initial process, the original image is divided into blocks of the same size and sub segmentation is performed for accurate extraction of images within the boundaries. A random matrix is used to swap the pixels of the neighboring sub blocks. Afterwards, each pixel is randomly exchanged for the neighboring blocks with a random matrix, then each block is encrypted with the proposed function and then the encrypted data can be stored in cloud. The proposed method uses Image Segmentation based Compression Model with Pixel Interchange Encryption (ISbCPIE) Model for providing high security to the Image transmitted in the network. Compressor is needed to achieve rapid transmission and efficient storage. The proposed model is compared with the traditional models and the results show that the proposed model security levels are better than the existing models.**

Keywords*—Image segmentation; image pixel extraction; pixel compression; pixel interchange; image security

I. Introduction

Typically, the quick progress of science and technology has utilized information technology in people's daily lives. During this era of digital data technology, the majority of private data and protected data are exchanged with electronic media [1]. The benefit of using electronic media for the sharing of personal data is that, technological devices convey information or photos in unusual conditions of safety, secrecy and honesty. An encryption framework for secure communication applications has been developed in order to find a response to the problem of security mode. The cryptographic technique is the process used to fix the original message with key to the protection of privacy and integrity of the information [2]. Encryption is a message encoding technique or key information [3]. By using the same key used for encryption, the first message or information will be exposed.

Cryptography can provide a solution, which can only be decrypted when the sender encrypts a message [4]. The aim of this research work is to study the compression and encryption combinations in digital photographs. These are both data compression and encryption processes [5] used to ensure maximum security for photos transferred. Image Segmentation is a process in which a digital image is separated into different subgroups, called Image Objects [6]. This is called Image Object, which can help to minimize the image ambiguity and thereby make the analysis of the image more straightforward. The effect of segmentation affects compression sophisticatedly.

Moore's Law and Storage Law are specifically linked to advances in imaging technology. The techniques needed to store these collected data and to transmit them should be enhanced if the amount of information in the world doubles every 18 months. As a result, the demand for compression techniques is enormous and is considered to be particularly significant in the current knowledge explosives. Image compression solves the problem of lowering the amount of information necessary to deliver the digital image with a decent image quality [7]. Compression of images is currently considered as an activated technology and a natural technique of handling the rising spatial resolution and changing TV broadcast standards of today's image sensor [8].

The proposed ISbCPIE algorithm is used to compress and encrypt images in order to resolve the above disadvantages. A new scalable coding scheme for encrypting images is given. In the encryption process of the proposed scheme, the pixel values are totally obscured. So an intruder cannot get statistical data from his original image. The coded data is then decomposed into many parts. By combining each part, the bit stream is achieved. Using the cryptographic key on the recipient side, the higher the resolution for the more bit streams the original content is retrieved.

II. Literature Survey

Aqeel-ur-Rehman et al. [2] researched Quaternion Discrete Cosine Transform (QDCT), which was much more knowledgeable about the difficulty of its conventional equivalents. The adopted QDCT has also been used to create and recognize a method of quantum image compression. The introduced compression model performs a search to determine the most significantly assessed DCT coefficients that has achieved. The added model therefore could simultaneously measure the DCT coefficients by using two predictions. In addition, the examination of the scheme adopted reveals that the scheme was better applied than the other classical models. The feasibility of the proposed solution has therefore been validated over conventional schemes.

A nonlinear, chaotic algorithm based primarily on tangents and power rather than linear functions was proposed by Jallouli et al. [3]. In order to provide multilevel security, S-box on chaotic maps are utilized. Here, with the aid of a logistic map and a 2D map, authors created dynamically 8/8 S-box. The first division in the plain image was 8 block sizes, followed by the blockbased shuffling of the image by a 2D map process in three separate chaotic maps. The shifted image is encrypted using a chaotic 1D logistic map sequence.

A new image encryption method has been introduced by Jiang et al. [6], which first arranges the image pixels based on RGB values and then transfers the intermediate image for encryption. The proposed image encryption algorithm and its security analysis as key space analysis, statistical analysis and differential analysis were defined in detail. The aim of chaotic key-based algorithm CKBA was to increase protection, with a discrete wavelet transformation and modified Key-base algorithm. Cryptanalysis has been carried out to examine the increased safety of the proposed algorithm. A permutation technique based on the three independent Diophantine equations system resolution has been implemented. An efficient chaotic block cipher with a chaotic logistic map has been suggested from this permutation algorithm. Luo et al. [7] proposed a random bit sequence generator algorithm, which was based on chaotical maps for image encryption. To generate necessary random bit sequences, Chaotic logistic and Tent maps were used.

Wang et al. [9] developed a threshold approach to generate the best bit-budget for the image waveform based on the 'Tchebichefpsychovisual' threshold. This bit-budget was designed to restore most of the quantization tables in image compression. The study results showed that the developed model can better improve the visual characteristics of the image result. The consistency of the visual image produces fewer objects and pixel deformation of the image [10]. A community of bits-budgets therefore provides an excellent creation with reduced bit lengths in image quality [11]. Finally, the method adopted was tested and positive research results were obtained by distinguishing between conventional systems.

Zhang et al. [12] introduced a new method to measure the finer limitations of fractal encoding to minimize their computational complication. The scaling constraint has been uncomplicated but proficiently calculated that rewards all the characteristics required to achieve convergence. It makes an uncomplicated distribution of two integers to replace the expensive process. In addition to their conventional models a customized HV block partition system and many new ways of developing an encoding and decoding cycle were adopted. From the analysis results, better output in a reduced period was verified in the technique used, similar to conventional models of fractal-dependent image compression.

Hayder et al. [13] employed an improved Embedded Zerotree Wavelet EZW to achieve better compression rates and PSNR to achieve loss-free image compression accordingly. The method adopted uses a novel symbolic map, symbolically more effectively, to minimize the count scanning and symbol duplicates of prevailing EZW. The adopt model was further developed to achieve a scalable image coding by efficient deployment of the interdependence of coloured planes. Simulation findings demonstrate, eventually, that the scheme adopted has support of both subjective and objective principles [14] for different compression schemes over the standard and other enhanced models.

In order to create a better image crypt method, Fathi et al. [15] have used vector quantization. The method is focused on vector quantization, one of the most common techniques of image compression. In vector quantization (VQ), the images are broken down into vectors and vector-by-vector sequentially encoded. The aims of this approach are to build a high-security picture crypto framework and reduce encryption and decryption algorithm computational complexity.

III. Proposed Model

In the field of image processing, immense amount of data need be considered and handled [16]. The overall compression issue is that the amount of information required to represent a digital image is reduced and the elimination of spatial and psycho-visual redundancies is the basis of the process of reduction [17]. The compression would be a waste if the re-constructed image from the compressed image is the same as the original. The way the image size can be obtained without greatly affecting its quality is image compression [18]. Uncompressed images have a higher time complexity than compressed images during transmission and reception [19]. To protect images against unauthorized access, such as scratching, intercepting and hacking, image protection is essential [20]. The image needs to be encrypted to provide security which leaves the picture unreadable and unmodified. Picture encryption [21] is a process by which images are encrypted and decrypted during transmission [22].

Implementing various safety measures at various levels is very necessary in order to provide information as a signal in the form of an image [23]. In the proposed model the image is initially segmented into sub images and then on sub images segmentation is performed and then pixel extraction is performed. The pixels extracted from the image are interchanged and then compression technique is applied. The compression technique will undergo encryption process for securing the image during data transmission. The proposed work framework is depicted in Fig. 1.

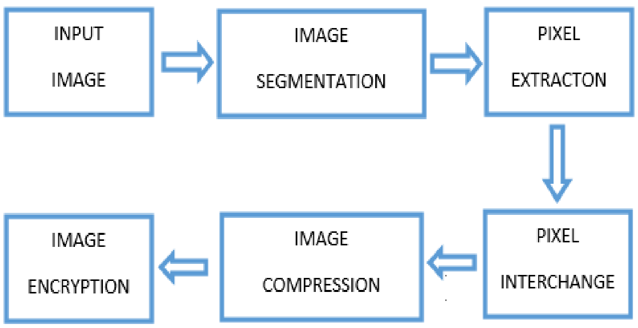


Fig. 1. Proposed Model Framework.

The process of the Image Segmentation based Compression Model with Pixel Interchange Encryption (ISbCPIE) Model is detailed in the algorithm.

Algorithm ISbCPIE

{

Input: Image I_N

Output: Encrypted Image $E(I_N)$

Step 1: Initially the image is provided as input which undergoes image segmentation. The sub image is again segmented further to accurately detect the pixels within the boundary and exact edges are detected. The process of segmentation is performed as

$$l_N(l_x, l_y) = \sqrt{\sum_{c=l_i}^{l_N} I(pix(i)) + (T - l_i(x-y))^2 \times pix_l^{I[l_i, l_j]} + \vartheta(I(x,y))} \quad (1)$$

Here I_N refers the image considered, x and y refers the adjacent pixels, pix(i) refers the extracted pixel, T is the maximum threshold value of the pixel intensity. ϑ refers the angle of the image. The image segmentation results in generation of sub images and again the sub image will undergo segmentation for accurate pixel extraction by considering the boundaries and edges.

Step 2: The process of arranging the images in the sequence for performing pixel extraction is performed as

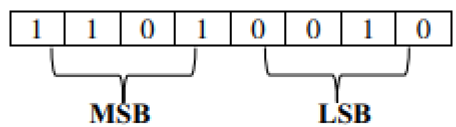
$$Sq(I(x,y)) = \sum_i pix(I(i) + I_N \vartheta_{i,j} + \vartheta(pix(i)) + exp\left(\frac{-(pix_j(i) - pix_i(j))^{\vartheta}}{\left(\frac{2\vartheta^2}{N}\right)}\right) \quad (2)$$

Step 3: After arranging the images in the sequence order, the pixels need to be extracted by considering the edges and boundaries. For a X*Y image, the first X bits are used to calculate the initial location of the permissible random pixel. In calculating the target location of the selected pixel, the last Y bits are used. It is repeated in X*Y numbers, ensuring that all the locations of the pixels are allowed. The next position available is chosen if a pixel is already allowed in the initial position or a target position is already filled. The pixels are extracted using the equation:

$$pix(I(x,y)) = \frac{\left(\sum_{i=1}^{h}\sum_{j=1}^{w}\left(x_{ij} - \overline{X}\right)\left(y_{ij} - \overline{Y}\right)\right) + \sum_{i=1}^{N} Min(Sq(i)) - Max(pix(I(x,y)))}{\sqrt{\left(\sum_{i=1}^{h}\sum_{j=1}^{w}\left(x_{ij} - \overline{X}\right)^2\right)\left(\sum_{i=1}^{h}\sum_{j=1}^{w}\left(y_{ij} - \overline{Y}\right)^2\right)}} \quad (3)$$

X,Y are the average values for original image pixels, and h and w are the height and width of the image, where x,y are adjacent image pixels with in the boundary, respectively.

Step 4: An image is defined as a two-dimensional I(x, y) function, where x and y are pairs of coordinates. The I(x,y) is a value called grayscale, which is the light intensity of pixels in coordinates (x,y). A pixel value can be translated to 8 binary numbers (bits). Four digits of the first are referred to as the LSB, which does not change the picture dramatically when changing value in this position. The second is called a 4 digit MSB, with an essential effect on the image by changing value in this place. The below representation shows the place of a bit value of a pixel value.



Step 5: The correlation coefficient of the image specifies how the relationship of the pixels adjacent to each other is calculated. The formula to calculate the correlation coefficient of the image is:

$$cc(x) = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad cc(y) = \frac{1}{N}\sum_{i=1}^{N} y_i$$

$$CC = \frac{\sum_{i=1}^{N} \frac{x_i - cc(x)}{y_i - cc(y)} + \theta(I(x,y)) - \min(pix(I(x,y)))}{\sqrt{\sum_{i=1}^{N}(x_i - cc(x))^2}\ \sqrt{\sum_{i=1}^{N}(y_i - cc(y))^2}} \quad (4)$$

Here x_i, y_i are the adjacent pixels of plain sub image at i position with angle $\vartheta$and N indicates the pixels count in the sub image.

Step 6: The pixels between cc(x) and cc(y) are exchanged by

$$\sum_{i=1}^{N} I\begin{pmatrix} x \\ y \end{pmatrix} = \sum_i I\begin{pmatrix} 1 & p \\ q & 1+pq \end{pmatrix}\begin{pmatrix} y \\ x \end{pmatrix} + \begin{pmatrix} p-y & p+x \\ q & x+y \end{pmatrix} \bmod CC.$$

$$PiM\begin{pmatrix} x \\ y \end{pmatrix} = \sum_{i=1}^{N} I\begin{pmatrix} x + (p-1+y) \\ y + (q-1+x) \end{pmatrix} \quad (5)$$

where, p and q are the adjacent boundaries of sub images extracted from an image.

Step 7: After pixel interchange is performed, the compression technique is applied on the pixel interchange matrix that is performed as

$$Si_{i,j}(I_N(i)) = \sum_{i=1}^{N} \Sigma_{i=1}^{N} I\binom{x}{y} + pix(i,j) + \{\frac{\|i_j - CC(x)_i\|}{\|j_j - CC(x)_y\|}\}^{*\,\theta} \quad (6)$$

$$Comp(I(X,Y)) = \sum_{i,j=0}^{N} \frac{pix(i,j)+\theta\left(Si_{i,j}(I_N(i))\right)-\sum_{i,j=0}^{N-1} pix_{i,j}(i-j)^2}{(i-j)^2+CC(x)-CC(y)} \quad (7)$$

Step 8: After the compression is completed the encryption technique is applied on the compressed image for providing security to the image during data transmission. The process of performing encryption undergoes several phases including key generation and then encryption. To generate the key the process involves in considering two random numbers as:

$$p = \left(\sum_{i=1}^{H}\sum_{j=1}^{W} Sq(I(x,y))\right) \bmod CC(x),$$

$$q = \left(\sum_{i=1}^{H}\sum_{j=1}^{w} Comp(i_i(x,y))\right) \bmod CC(y).$$

After calculating the p and q values, the key is calculated as

$$TempK(i) = \sum_{I=1} \sum_{j=i-1} p_j^l * p_i^N + \sum_{i,j\in N} Si_{i,j}(I_N(i)) + \sum_{i=1} \log pix(x, y_n = 0|X:H+Y:W) \quad (8)$$

$$PrivK(i) = \sum_{I=1}^{N} TempK(i) + \sum_{i}^{N} \mathrm{CC(x)} \log S_{in} - \sum_{i} (1-\mathrm{N}+\mathrm{CC(y)}) \log(1-S_i) \quad (9)$$

Step 9: The image encryption technique is applied on the pixel interchanged matrix as:

T1= $PiM\binom{x}{y}$ ⊕ p*q

T2= T1<<p ⊕$PrivK(i)$

T3= T2>>q ⊕T1>>p ⊕$PrivK(i)$-q

T4= CC(x) + leftcirshif(T3) +CC(y) ⊕$TempK(i)$⊕$PrivK(i)$+mod(p,q)

T5= T4>>Th⊕ T2<<Th ⊕ ($PrivK(i)$+Th)

}

The image after performing the image pixel extraction, compression and encryption, the encrypted image can be stored in cloud as the data is very secured.

IV. Result

The proposed model is implemented in ANACONDA SPYDER for performing image segmentation, pixel extraction and pixel interchange to perform encryption. Numerous security analysis tests were performed in order to determine the efficiency of the suggested methodology on images. The images are considered from the links https://www.kaggle.com/puneet6060/intel-image-classification?select=seg_train and https://data.mendeley.com/datasets/3hfzp6vwkm/3. For every single image, each pixel in horizontal, vertical or diagonal directions is highly correlated with its neighboring pixels. An attacker may use this connection to carry out statistical assaults. The cryptographic algorithm should therefore construct an encrypted picture with a low pixel correlation to resist such statistical attacks. In the three directions referenced, 2,800 pairs of adjacent pixels are chosen randomly in two pictures to determine a correlation in both the single-picture and cipher-image directions. The proposed model is evaluated by considering several parameters like image segmentation time levels, pixel extraction time levels, compression time levels, pixel interchange accuracy, Encryption Accuracy, Encryption Time Levels, Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR). The proposed model provides a secured platform for transmitting the images in the network.

For gray images with 256 levels, where each gray level is considered to be equi-probable, its entropy will be 8sh (or bits). An image encryption algorithm should preferably offer an encrypted image with equipment that is gray. The entropy values for the considered image when applied on different algorithms are indicated in the Table I.

TABLE I. ENTROPY VALUES

Algorithm Applied	Entropy (sh)
Proposed ISbCPIE	8.24
Chaotic Cryptography (CC) [3]	7.86
Block Cryptosystem based on Iterating a Chaotic Map (BCICM) [17]	7.67
Chaos-based PWL Memristor (CPWLM) [18]	7.52

The proposed ISbCPIE model is compared with the traditional Chaotic Cryptography (CC), Chaos-based PWL Memristor, Block Cryptosystem based on Iterating a Chaotic Map (BCICM), Chaos-based PWL Memristor (CPWLM) models. The proposed model initially performs image segmentation and then again each segmented image is segmented for accurate pixel extraction with exact edges and boundary values. The image segmentation time values are depicted in Fig. 2.

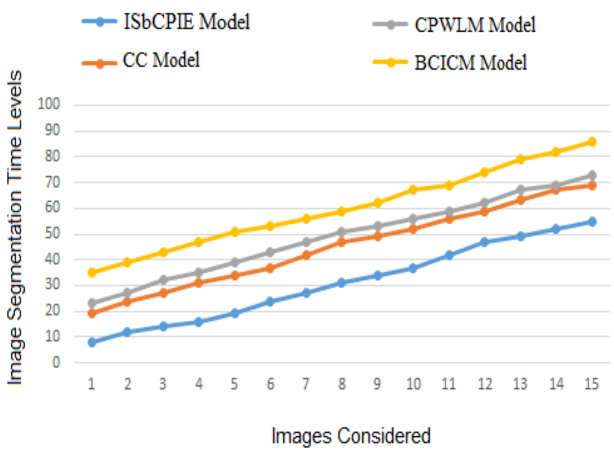


Fig. 2. Image Segmentation Time Levels.

The image considered will undergo segmentation and then from each sub image, pixel extraction is performed for considering the values to perform multiple operations like compression and applying cryptography techniques. The Pixel extraction time levels of the proposed and traditional models are depicted in Fig. 3.

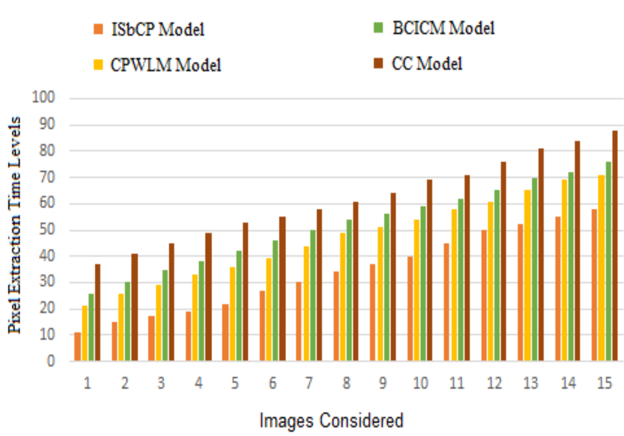


Fig. 3. Pixel Extraction Time Levels.

The extracted pixels undergo the process of interchanging the pixels positions to a specific position for providing the security levels during image transmission. The pixel interchange accuracy levels of the proposed and existing models are indicated in Fig. 4.

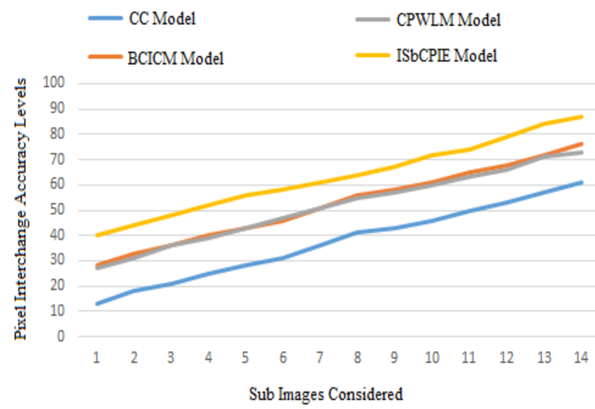


Fig. 4. Pixel Interchange Accuracy.

The pixel interchanging model allows the users to increase the security levels in hiding the image from the attackers. The image pixels which are interchanged are compressed to reduce the size and for quick data transmission. The Image pixel compression time levels are indicated in the Fig. 5.

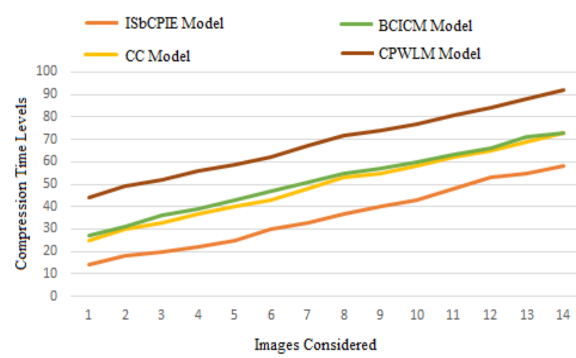


Fig. 5. Compression Time Levels.

The original image is considered as input and then it undergoes image segmentation. All image segments undergo pixel extraction and pixel bit interchange for improving the security levels during data transmission. The compression technique is applied on the image segments and then encryption is performed. The Original image and encrypted image is represented in Fig. 6.

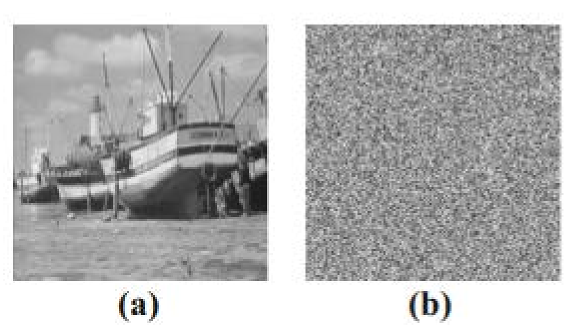


Fig. 6. (a) Original Image (b) Encrypted Image.

The proposed encryption model is effective and the encryption accuracy of the proposed model is compared with the traditional models. The encryption accuracy levels are indicated in Fig. 7.

Fig. 7. Encryption Accuracy.

The time for performing encryption in the proposed model is low when compared to traditional methods. The encryption time levels are indicated in Fig. 8. The Table II illustrates the time levels of performing encryption on various image sizes.

Fig. 8. Encryption Time Levels.

TABLE II. TIME FOR ENCRYPTION FOR VARIOUS PICTURE SIZES

Image size	**Average Pixel Interchange Time (ms)-Proposed Model**	**Average Pixel Interchange Time (ms)-Existing Model**	**Average Encryption Time (ms)-Proposed Model**	**Average Encrypti on Time (ms)-Existing Model**
256 x 256	4	9	5	12
512 x 512	12	17	15	23
1024 x 1024	43	91	63	97

The cryptographic value of the proposed image encryption structure is calculated by measuring the Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR). The process of calculating MSE and PSNR are:

$$MSE = \frac{1}{h \times w} \sum_{i=1}^{h} \sum_{j=1}^{w} \left(a_{ij} - b_{ij}\right)^2$$

The mean square error (MSE) representation of the proposed and the existing models are represented in Fig. 9.

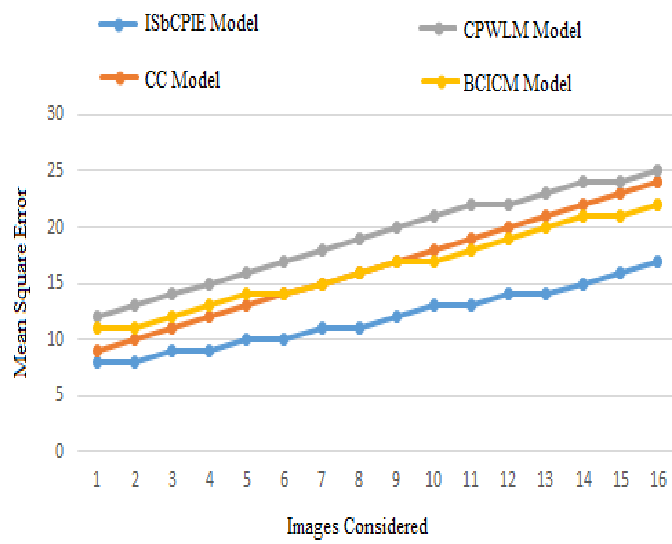


Fig. 9. Mean Square Error.

$$PSNR = 10 \log_{10}\left(\frac{255^2}{MSE}\right)$$

The Peak Signal-to-Noise Ratio (PSNR) representation of the proposed and the existing models are represented in Fig. 10.

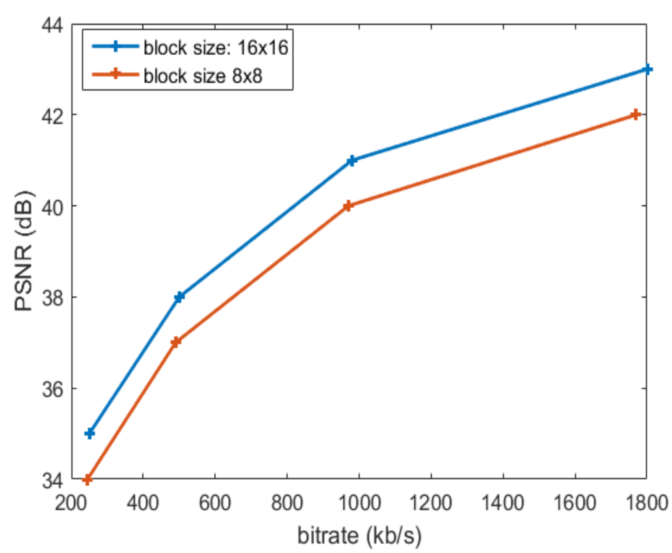


Fig. 10. PSNR Representation.

V. Conclusion

Digital files are communicated at any moment, on any computer and with everyone on the planet. In this digital era, lakhs of users are depending on digital communication and seek to communicate efficiently and safely. There is a continuous improvement in communication with stronger demands on productivity and protection, where effectiveness is data compression and security is encryption. Digital communication can be based on a structure which is expressed in two heterogeneous and often contradictory operations, but which must be applied to the original file in order to ensure efficiency and safety. The enemy of compression is randomness, but on the other hand encryption needs to add a randomness to digital data to offer protection. These two operations are compression and encrypting. The proposed algorithm focuses on the simultaneous compression and encryption of random pixel interchange model. Divide the image into the blocks of equal size in the proposed process, and every block is again subdivided into frequencies and then performed with pixel interchange and then encrypts every substructure and encapsulates the respective sub-block in one block. For all sub-blocks and blocks, the same process is performed. Random pixel exchange between compression and encryption blocks is performed. The encrypted data can be securely stored in cloud. The algorithm proposed improves the flexibility and robustness of image protection. The proposed model accuracy and security levels are also high when compared to traditional models. In future the key generation techniques need to be concentrated more to enhance the security levels of data during transmission. In future, the computational complexity levels of the proposed model can be reduced by the usage of feature reduction model to improve the accuracy levels.

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Cyclic Path Planning of Hyper-redundant Manipulator using Whale Optimization Algorithm

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***Abstract*—This paper develops a path planning algorithm of hyper-redundant manipulators to achieve a cyclic property. The basic idea is based on a geometrical analysis of a 3-link planar series manipulator in which there is an orientation angle boundary of a prescribed path. To achieve the repetitive behavior, for hyper-redundant manipulators consisting of 3-link components, an additional path is chosen in such away so that it is a repetitive curve which has the same curve frequency with the prescribed end-effector path. To solve the redundancy resolution, meta-heuristic optimizations, namely Genetic Algorithm (GA) and Whale Optimization Algorithm (WOA), are applied to search optimal trajectories inside local orientation angle boundaries. Results show that using constant of the local orientation angle trajectories for the 3-link component, the cyclic properties can be achieved. The performance of the WOA shows very promising result where generally it obtains the lowest fitness value as compare with the GA. Depending on the complexity of the path planning, dividing the path into several stages via intermediate points may be necessary to achieve the good posture. The performance of the swarm based meta-heuristic optimization, namely the WOA, shows very promising result where generally it obtains the lowest fitness value as compare with the GA. Using the developed approach, not only the cyclic property is obtained but also the optimal movement of the hyper-redundant manipulator is achieved.**

Keywords*—Hyper-redundant; path planning; whale optimization algorithm; sustainable manufacturing

I. Introduction

Sustainability becomes an important achievement in all aspect of an engineering design, including in the robotics field. Optimal motion has been remarked as important goal in the sustainability design of the robotics system [1-3]. Eco-programming refers to approach to improve the energy efficiency on the existing plants with minimum investment cost [1]. In the robotics applications, eco-programming leverage on the developing the motion planning to reduce the energy consumption. The eco-programming can be classified to two types which are the trajectory optimization and the scheduling optimization. In the trajectory optimization, it is necessary to generate the optimal path and/or the motion profile. One of strategies to achieve the energy efficiency is by minimizing the robot motion [2]. The configuration of the robots is in the state of the most energy-efficient when the end-effector path is pre-defined and the path of the robot has been optimized [3].

This paper addresses the path optimization of the hyper-redundant manipulator. The hyper-redundant manipulator involves the high degree of redundancy so that it has many advantages regarding their capability to avoid obstacles and achieve complex form of locomotion and grasping [4]. Because of these potential benefits, recently the hyper-redundant manipulator has been widely applied not only in the manufacturing job [5] also in challenging environments such as in the medical application [6] and the operation for rescue duty during the natural disaster [7].

The Jacobian based approach is the standard method to solve the Inverse Kinematic (IK) for the hyper-redundant manipulator [7]; however, this approach requires the matrix inversion which becomes computationally expensive for the hyper-redundant manipulator since it involves very large Degree of Freedom (DOF) [4, 8]. For the hyper-redundant case, alternative approaches have been proposed to solve the path planning problem. Ayten et al. [5] developed two methods for trajectory optimization of redundant/hyper-redundant manipulator. In their first method, the kinematic and dynamic constraints were solved sequentially according to the cost function to avoid the inverse dynamics computation. The second method used a virtual link concept replacing all the redundant link for eliminating impossible configuration before the inverse dynamic model was employed. Simulations were

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conducted using the 3-link and 8-DOF planar series hyper-redundant manipulators. Ananthanarayanan and Ordinez [9] proposed a multi-pass sequential localized search technique to solve the path planning of the hyper-redundant manipulator in the presence of obstacles. The problem was modeled as shortest path optimization where the configuration space was searched based on the cost function which needed to be optimized. Dasgupta *et al.* [10] applied a variational approach to optimize the path of the hyper-redundant manipulator in high dimensional C-space. Shukla *et al.* [11] employed the variational principles by formulating the path planning as constrained optimization. The monotonic optimality concept was proposed to obtain the optimal path between resulting end configurations. Potential fields-based path planning of the hyper-redundant manipulator had been studied by Concur [12]. An algorithm, namely point settling algorithm was proposed. A smooth path consisting of points which were closed enough each other needed to be found using harmonic potential field. The tip of each link needs to be maintained until the goal of motion was reached. Lanteigne and Jnifene [13] proposed a biologically inspired node generator for the hyper-redundant manipulator planning using a probabilistic roadmap. Chirikjian and Burdick [14] used a continuous backbone curve approach to model the kinematic of the hyper-redundant manipulator operated in uneven solid terrain.

Among many possible approaches to solve the path planning of the hyper-redundant manipulator, the geometrical approach is one of the most popular methods. Yahya *et al.* [8] developed the geometrical based approach by considering the joint angle between the adjacent links to be the same. By this approach, the singular configuration can be avoided since geometrically two or more joints were impossible to lining up each other. Menon *et al*. [7] proposed a novel optimization algorithm obtained from calculus variation for the motion planning of the hyper-redundant manipulator. The algorithm, which was purely geometric, computed the motion of all joints in such away so that all links avoid the obstacles. Sardana *et al.* [6] presented a simple geometrical approach to solve the IK of four degree of freedom in–Vivo robots when it inserted to the tool channel of the endoscope for taking a biopsy in the stomach. Chirikjian and Burdick [15] proposed strictly geometric algorithm for the hyper-redundant manipulator using a tool, namely tunnel, to avoid collision with obstacles. Differential geometry was used to derive the equation which guarantees that the manipulator sections were confined to the tunnel to avoid obstacles.

Despite many approaches have been proposed to solve the path planning of the hyper-redundant manipulator, only few papers address the methodology to achieve the cyclic property. The cyclic property is very essential in the manipulator motion since it exhibits the predictable behavior. The predictable behavior yields the system which is easier to be maintained than the system with random or unpredictable behavior [16]. It confines the motion within the robot operational area so that it is safe for the robot. Marcos *et al.* [17] proposed the combination of the GA and closed-loop pseudoinverse. The performance of the Open Loop GA (OLGA) and Closed Loop GA (CLGA) were compared. Result showed that CLGA had good performance than that of the CLGA where the CLGA yielded the repetitive behavior. However, using the CLGA approach, the matrix inversion was still necessary. The fractional calculus had been studied to solve the hyper-redundant path planning problem [18, 19]. This approach needed to find the value of α in order to get the cyclic joint angle trajectories.

This paper develops the path planning approach of the *n*-link planar series hyper-redundant manipulator to achieve the cyclic properties based on the geometrical approach incorporating the meta-heuristic optimization. The hyper-redundant manipulator is modeled as composition of the 2-link and 3-link components. The last 3-link component tracks the end-effector path with respect to position of the previous link as the moving base. The constant parameter, *k*, which gives the optimal path needs to be searched within this boundary employing the meta-heuristic optimization, namely the GA and WOA. As an advantage, since the geometrical approach is employed, the proposed approach does not need the matrix inversion. Furthermore, both the optimization criteria which is the minimum joint angle path and the cyclic property which yields the predictable behavior can be achieved.

The presentation of the paper is in the following. The path planning optimization is presented in Section 2. Section 3 presents the proposed path planning method. Joint angle trajectories generation is described and the algorithm to achieve the cyclic property for the hyper-redundant planar series manipulator is presented. Section 4 presents the meta-heuristic optimizations, which are the GA and the WOA. Section 5 presents numerical experiments of the path planning of the 5-DOF and 12-DOF planar series hyper-redundant manipulator.

II. Path Planning Optimizations

The path planning is modeled as the constraint optimization problem with the optimization objective is to minimize the joint angle path:

$$\text{Min } F_{path} = \sum_{i=1}^{n} \int_0^1 \sqrt{1 + \left(\frac{d\theta_i(r)}{dr}\right)^2}\, dr \tag{1}$$

Subject to:

$$\theta_{imin} \leq \theta_i \leq \theta_{imax} \tag{2}$$

$$x = l_1 cos(\theta_1) + \ldots . l_i cos(\theta_1 + \theta_2 + \ldots \theta_i) \tag{3a}$$

$$y = l_1 sin(\theta_1) + \ldots . l_i sin(\theta_1 + \theta_2 + \ldots \theta_i) \tag{3b}$$

$$x_e = f(t) \quad ; \quad y_e = g(t) \tag{4}$$

$$(x_e, y_e) = (x, y) \tag{5}$$

$$\left((x_{link}, y_{link}) \cap obs\right) = \emptyset \tag{6}$$

where (x_e, y_e) and (x, x) are desired end-effector position and actual end-effector position, θ_i is a joint angle of *i*th link, l_i is length of *i*th link, $\theta_{imin/max}$ is minimum/maximum *i*th joint angle, (x_{link}, y_{link}) and *obs* are link configurations and obstacle area, with *n* is number of links, respectively.

Equation (2) is the constraint of the joint angle. Equations (31, 3b) are the forward kinematics of the planar series hyper-redundant manipulator.

III. Proposed Path Planning

For the IK problem of 3-DOF planar series manipulator, it has the analytic solution using the geometrical approach in the following [20]:

$$w_x = x_p - l_1 \cos(\theta_g); w_y = y_p - l_1 \sin(\theta_g) \quad (7)$$

$$c_2 = \frac{(w_x{}^2 + w_y{}^2 - l_1{}^2 - l_2{}^2)}{2 l_1 l_2} \quad (8a)$$

$$s_2 = \pm\sqrt{1 - c_2{}^2} \quad (8b)$$

$$\theta_2 = a\tan 2\,(s_2, c_2) \quad (9)$$

Second and third joint angles can be obtained by following equations:

$$\Delta = w_x{}^2 + w_y{}^2; s_1 = \frac{(l_1 + l_2 c_2) w_y - (l_2 s_2 w_x)}{\Delta} \quad (10)$$

$$c_1 = \frac{(l_1 + l_2 c_{21}) w_x + (l_2 s_{21} w_y)}{\Delta}; \theta_1 = a\tan 2\,(s_1, c_1) \quad (11)$$

$$\theta_3 = \theta_g - \theta_3 - \theta_1 \quad (12)$$

where θ_{1s}, c_1, s_1 and θ_{3s} are the first joint angles, the cosine of θ_{1s}, the sine of θ_{1s}, and the third joint angle, respectively.

Equation (8a) can be expressed into more useful functions as follows:

$$c_2 = A_x \cos\theta_g + A_y \sin\theta_g + k_p$$

$$= A_p \cos(\theta_g - \varphi_p) + k_p \quad (13)$$

$$A_x = \frac{-l_3 x_p}{l_1 l_2}; A_y = \frac{-l_3 y_p}{l_1 l_2} \quad (14)$$

$$\varphi_p = a\tan 2\,(A_y, A_x); k_p = \frac{R^2 + l_3{}^2 - l_2{}^2 - l_1{}^2}{2 l_1 l_2};$$

$$R = \sqrt{x_p{}^2 + y_p{}^2} \quad (15)$$

where ϕ_p, k_p, A_p, and R are a phase shift, a vertical shift, an amplitude, a radius from the fix base, respectively.

A. *Joint Angle Trajectory Generation*

This paper proposes to model the hyper-redundant manipulator as components of 2-link and 3-link.

For the 2-link component, the joint angle trajectories are modelled as the polynomial degree sixth as follows [21]:

$$\theta_k = a_{6k} r^6 + a_{5k} r^5 + a_{4k} r^4 + a_{3k} r^3 + a_{0k}$$

$$a_{0k} = \theta_{ik}; a_{5k} = -3a_{6k} - 6\theta_{ik} + 6\theta_{fk};$$

$$a_{4k} = 0.5(-9a_{6k} - 5a_{5k}) \quad (16)$$

$$a_{3k} = \theta_{fk} - \theta_{ik} - a_{6k} - a_{5k} - a_{4k}\ ; r = \frac{t}{T\_}$$

where θ_k, θ_{ik}, θ_{fk}, a_{nk}, and r, are the joint angle of kth link, the joint angle of k^{th} link at t=0 s, the joint angle of k^{th} link at t=$T_$s, nth polynomial coefficient of kth link, and linear time-scale, respectively.

$T\_$ is the period of the repetitive curve or the time to conduct one complete end-effector repetitive curve. By designing the joint angle at initial point of repetitive curve, t=0 s, to the final point of repetitive curve, t=$T\_$ s, as the same value, the periodic joint angle trajectories can be achieved. Depending on the complexity of the path planning, the intermediate points may be needed to achieve the good posture.

For the 3-link component, the joint angle trajectory is simply chosen as constant value as follows:

$$\theta_{gk}(t) = k \quad (17)$$

where θ_{gk} and k are the local orientation angle boundary of kth 3-link component and constant parameter, respectively.

The value of A_p, k_p, and ϕ_p are functions of tracked positions (x_p, y_p). Since (x_p, y_p) trajectories are varied, then A_p, k_p, and ϕ_p continuously changes, there will be the lower bound trajectories of , θ_{gmin}, and the upper bound trajectories, θ_{gmax}, of θ_{gk} constructing a boundary. Since the redundancy resolution with respect to the position of previous 2-link or 3-link components has been mapped into the boundary, any arbitrary function, *F(t)*, generated inside the boundary of θ_g are possible solutions. The position of links can be obtained from the forward kinematics, Eq. (3).

For the 3-link component, it has the joint angle component as follows:

$$\theta = [\theta_k \quad \theta_{k+1} \quad \theta_{k+2}] \quad (18)$$

where θ_k is the joint angle of kth link.

Each component of θ can be determined as follows:

$$\theta_k = \theta_{1s} - \sum_{n=1}^{j-1} \theta_n\ ;\ \theta_{k+1} = \theta_{2s}\ ;\ \theta_{k+3} = \theta_{3s} \quad (19)$$

where θ_{1s}, θ_{2s}, θ_{3s} are Equation (11), Equation (9), Equation (12), respectively.

The above joint angle is computed with respect to the moving base where it can be obtained by Eqs. (7-12) through modifying equation (7) as follows:

$$w_x = (x_k - x_{k-1}) - l_k \cos(\theta_g)$$

$$w_y = (y_k - y_{k-1}) - l_k \sin(\theta_g) \quad (20)$$

where l_k and (x_k, y_k) are length of kth link and position of the end of kth link, respectively.

The local orientation angle represents the total local joint angle, $\theta_{gk} = \theta_k + \theta_{k+1} + \theta_{k+2}$

B. *Algorithm*

Fig. 1 shows the flow chart of the proposed algorithm. The proposed path planning to achieve the cyclic property of the hyper-redundant manipulator can be computed using the following procedure:

1) *For the hyper-redundant robot consist of 3-link*

a) Define an additional path as moving base of 3-link components. The additional path can be chosen as repetitive path having same curve frequency with the end-effector path. The first 3-link component has the fix base.

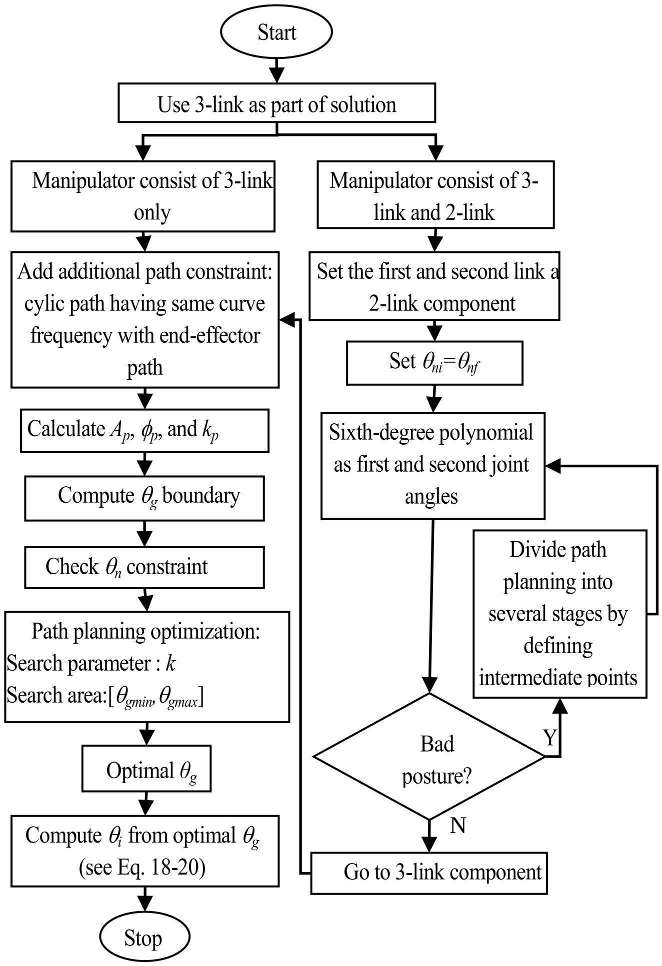


Fig. 1. Flow Chart of the Proposed Geometrical based Approach.

b) Calculate Amplitude A_p, phase shift ϕ_p, and the vertical shift k_p to achieve the moving base for 3-link components. The last 3-link component tracks the end-effector path.

c) Compute lower bound :θ_{gmin} and upper bound θ_{gmax} for all sampling points.

d) Check constraint of joint angle. The boundary may decrease if there is the joint angle constraint.

e) Optimize the orientation angle trajectories, Eq. (17), using the meta-heuristic optimization.

f) Go to step 3.

2) *For the hyper-redundant robot consist of 2-link and 3-link*

a) Set the first and second link as 2-link component.

b) Define point A and point B inside the intersection of workspace of 2-link and 3-link components.

c) Use polynomial degree sixth as the first and second joint angles. Set joint angle at initial position of the repetitive curve, t=0, and final position of the repetitive curve, $t=T$_, as the same value to achieve cyclic property.

d) In the case of bad posture detected, divide the path planning into several stages by defining the intermediate point and do step (iii) for all stage. To achieve connectivity between the current stage and the previous stage, final joint angle of kth stage become initial joint angle of (k+1)th stage.

e) Calculate the position of the end of 2-link component (x_2,y_2), which becomes the moving base of next 3-link component, using forward kinematics.

f) For next 3-link components, do step (a) to (d) of step 1 with respect to the moving base. The moving base for the first 3-link component is obtained from (v) result.

g) Construct the overall orientation angle boundary for one cyclic time by combining the boundary of the overall stage. The boundary should be connected between the neighboring stages.

h) Optimize the local orientation angle trajectories, Eq. (17), using the meta-heuristic optimization.

3) Compute θ_i from optimal θ_g trajectories using Eqs. (7-12) for the fixed base. For the moving base, use Eqs. (18-20).

IV. Meta-Heuristic Optimizations

To choose the best solution among many possible solutions of the IK, the meta-heuristic optimizations, which are the GA and the WOA are employed.

A. Fitness Functions

The optimal solution with the optimization objective is to minimize joint angle traveling distance considering the constraints as follows:

$$F_{obj} = \begin{cases} 0 & if\ \exists(x_{link}, y_{link}) \cap \ obs \\ F_{path} & else \end{cases} \tag{21}$$

where F_{path} is equation (1).

In the case there is no obstacle, the objective function is F_{path}. This paper considers the intermediate points which are pre-defined, and the orientation angle trajectories of 3-link component are optimized. Thus, the parameter to be searched in the optimization is k in Eq. (19). The total number of searching parameter depends on the number of links.

B. Genetic Algorithm

The GA has three main procedures which are reproduction, crossover, and mutation. The searching parameter is represented as the chromosome. A crossover is a process of randomly picking one or more individual as parents and swapping segments of the parents. The mutation is the GA part which corresponds to the search space exploration. This paper employs real code GA where random resetting mutation is used. In this scheme, randomly chosen gene assigns to be changed with a random value.

The following is the GA pseudocode of the path planning of the hyper-redundant manipulator:

Begin
t=0
Initialize parameter of the GA, chromosome is k, equation (17)
Calculate θi, equations (7-12, 18-20)
Compute the fitness, equation(21)
Evaluate individuals in population
Store best individual
If number iteration<=maxit
t=t+1
Create mating pool
New offspring by crossover
Mutation
Go to step 3
Output best and stop
End

C. Whale Optimization Algorithm

The WOA is relatively new meta-heuristic optimization technique inspired from the bubble-net hunting strategy of humpback whales proposed by [22]. There are three main important scenarios in the WOA, which are Encircling prey, bubble-net attacking (exploitation phase), and Search for prey (exploration phase).

The search agents update their positions approaching the best search agent. This behavior is expressed by:

$$\vec{D} = \vec{C}\vec{X}^{*}(t) - X \tag{22a}$$

$$\vec{X}(t+1) = \vec{X}^{*}(t) - A.\vec{D} \tag{22b}$$

where t, $\vec{A}$, $\vec{C}$, X^*, $\vec{X}$, and | | are the current iteration, a coefficient vector, the current position vector of the best solution, the position vector, the absolute value, and an element-by-element multiplication. X^* needs to be updated in the computation when there is a better solution.

$\vec{A}$ and $\vec{C}$ are expressed mathematically as follows:

$$\vec{A} = 2\vec{a}.\vec{r} - \vec{a} \tag{23a}$$

$$\vec{C} = 2.\vec{r} \tag{23b}$$

$\vec{a}$ is decreased from 2 to 0 in exploration and exploitation phases and $\vec{r}$ is a random vector in [0,1].

The following is the WOA pseudocode of the path planning of the hyper-redundant manipulator:

Initialize whales population X_i, with positions=k (Eq. 17)
while *(t < maximum number of iterations)*
Calculate θi, Eqs. (7-12, 18-20)
Calculate the fitness of each search agent
X = the best search agent*
for *each search agent*
Update a, A, C
If1 *(ρ<0.5)*
if 2 *(|A|<1)*
Update the position of the current search agent
Else if2 *(|A|>=1)*
Select a random search agent (Xrand)
Update the position of the current search agent
End if2
Else if 1 (ρ>=0.5)
Update the position of the current search
End if1
End for
Check if any search agent goes beyond the search space and ***amend*** *it*
Calculate *θi, Eqs. (7-12, 18-20)*
Calculate the fitness of each search agent
Update X if there is a better solution*
t=t+1
End while
*Return X**

V. Result and Discussion

A numerical experiment has been conducted in MATLAB environment by writing a computer program. For the GA, the real value coded is used with the selection rate and the mutation rate are 0.5 and 0.1, respectively. Both GA and WOA are evaluated using 100 numbers of iterations and 20 individuals in the population. The value of the searching parameter, k, is set to be four decimal place accuracies.

A. 5-DOF

This section applies the proposed approach to the case 3 in [8] with the goal is to achieve the optimal path while satisfying the cyclic property. Yahya et al. [8] proposed to apply the geometrical approach for the planar 5-DOF hyper-redundant manipulator by setting the second, third, fourth, and fifth joint angles to have the same value so that the singular configuration can be avoided while the good posture can be achieved; however, they did not discuss how to achieve the cyclic property.

The 5-DOF planar series manipulator with length, l= [22 20 18 16 14] cm, tracks the curve as follows:

$$x(t) = 30\cos(t+3) - 25 \tag{24}$$

$$y(t) = 30\sin(t+3) + 30$$

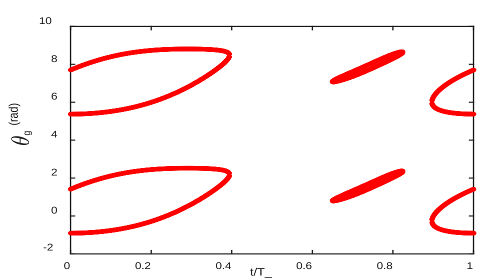
The above curve has period $T\_=2\pi$ second. Using the proposed approach, the moving base, which is the position of the end of second link (x_2, y_2), should be kept inside the workspace of the 3-link components. Fig. 2a shows the local orientation angle boundary using one step path planning with initial/final first joint angle: θ_{1i} = θ_{2i} = -0.8 and initial/final second joint angle: θ_{1f} = θ_{2f} = 0.8. Using the value of a_{6k}=10 and θ_{gk}=3, Fig. 2b shows the posture to track the above curve. It can be observed that there are bad postures involved.

To achieve the good posture, the proposed path planning is applied by dividing the path planning step into four stage every period time as follows:

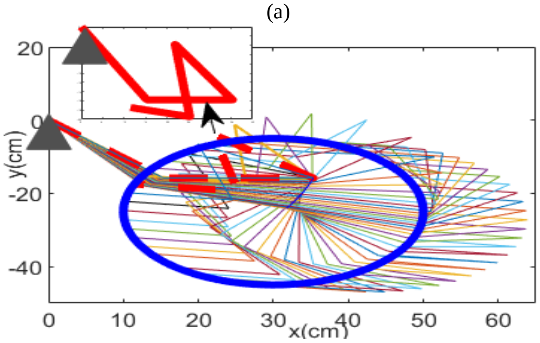
$$r(t) = \begin{cases} \frac{2}{\pi}t & dT\_ \le t \le \frac{T}{4}dT\_ \\ t - \frac{2}{\pi} & \left(\frac{T}{4}dT\_ + dT\_\right) \le t \le \left(\frac{T}{2} + dT\_\right) \\ \frac{2}{\pi}(t-\pi) & \left(\frac{T}{2} + dT\_\right) \le t \le \left(\frac{3T}{4} + dT\_\right) \\ \frac{2}{\pi}\left(t - \frac{3\pi}{2}\right) & \left(\frac{3T}{4} + dT\_\right) \le t \le \left(T\_ + dT\_\right) \end{cases} \tag{25}$$

where r, $T\_$, and d are the linear time-scale, period, and the whole number, respectively.

For the first 2-link component, at each stage, the polynomial degree sixth, Eq. (16), is generated with the definition of r as Eq. (25). Using this definition, every stage is computed from parameter 0 to 1. The initial joint angle and final joint angle of each stage for the first and second links are presented in Table I.



(a)



(b)

Fig. 2. One Time Path Planning (a) Boundary (b) Containing Bad Posture.

TABLE I. INITIAL AND FINAL ANGLES OF FIRST AND SECOND JOINT

Joint(rad)		**I**	**II**	**III**	**IV**
1st	*Initial*	-2.75	-2.6	-1.8	-2
	final	-2.6	-1.8	-2	-2.75
2nd	*Initial*	1.3	1.8	1	2
	final	1.8	1	2	1.3

The final joint angle of kth stage becomes the initial joint angle of (k+1)th stage to achieve connectivity between the current stage and the previous stage. The position of the end of second link (x_2, y_2) is obtained from the forward kinematics. Using a_{6k}=0, with respect to this second link position which become the moving base of the 3-link component, the local orientation angle boundary is illustrated in Fig. 3.

The local orientation angle trajectories, $\theta_{gk}(t)$, should be kept inside the angle domain boundary. This paper considers the constant trajectories as Eq. (17). The optimum value of k needs to be searched inside the local orientation angle boundary. The geometrical approach of the 3-link component has two possible postures obtained from the positive and negative roots of Eq. (8b). The optimal configuration come from the both possible postures is searched using the GA and the WOA. Table II presents the path planning results of the GA and the WOA for both possible postures. Fig. 4a and 4b shows the fitness value evolution for the GA and the WOA for the positive root and the negative root, respectively. For both cases, it shows that the WOA has lowest fitness value as compare with the GA results.

Using the optimum value of k from the WOA, the joint angle trajectories for m-cycle of end-effector movement from the positive and negative roots are illustrated in Fig. 5 and 6, respectively. It can be observed that the joint angle come from the both possible postures are periodic so that they are satisfy the cyclic property. Fig. 7a and 7b illustrate the postures for each stage of the path planning and overall stage of one cycle of end-effector movement, respectively, for the positive root. Fig. 8a and 8b show the postures for each stage of the path planning and overall stage of one cycle of end-effector movement, respectively, for the negative root.

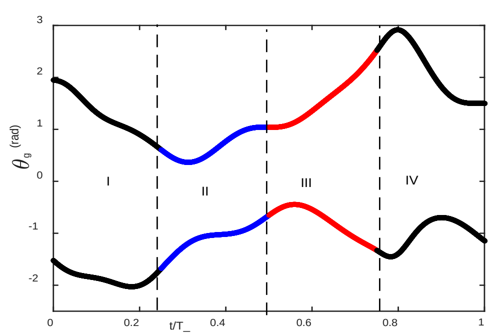


Fig. 3. Boundary of 4-Stage Path Planning.

TABLE II. PATH PLANNING RESULTS

Methods	Fitness	k
GA	20.2871801	-0.2838
WOA	20.2871779	-0.2828

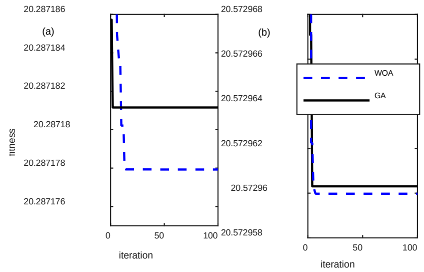


Fig. 4. Fitness Value Evolution (a) $+\sqrt{1-c_2{}^2}$ (b) $-\sqrt{1-c_2{}^2}$.

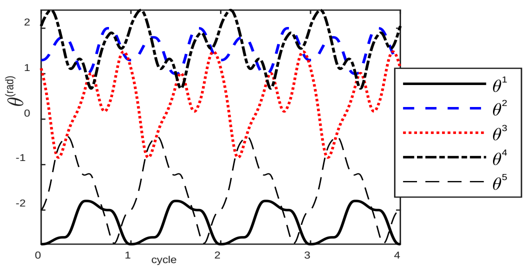


Fig. 5. Joint Angle for M-Number of Cycles, $+\sqrt{1-c_2{}^2}$.

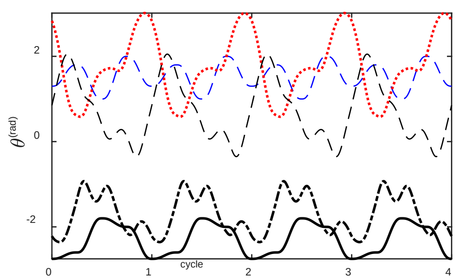


Fig. 6. Joint Angle for M-Number of Cycles, $-\sqrt{1-c_2{}^2}$.

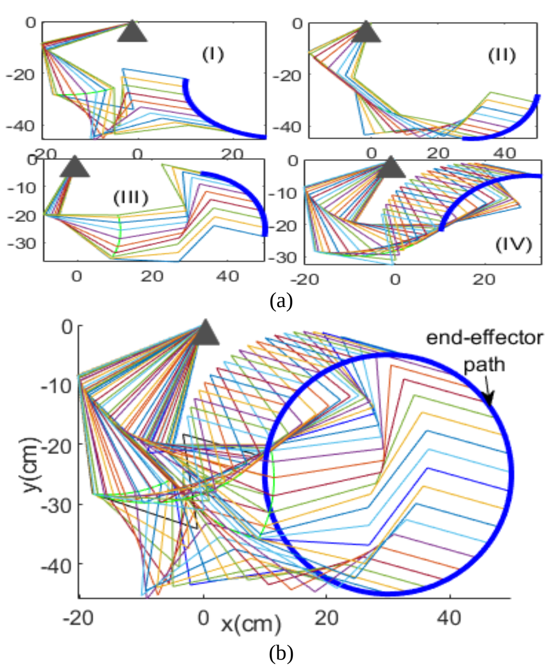


Fig. 7. Posture= $+\sqrt{1-c_2{}^2}$ (a) Each Stage (b) Overall Stage.

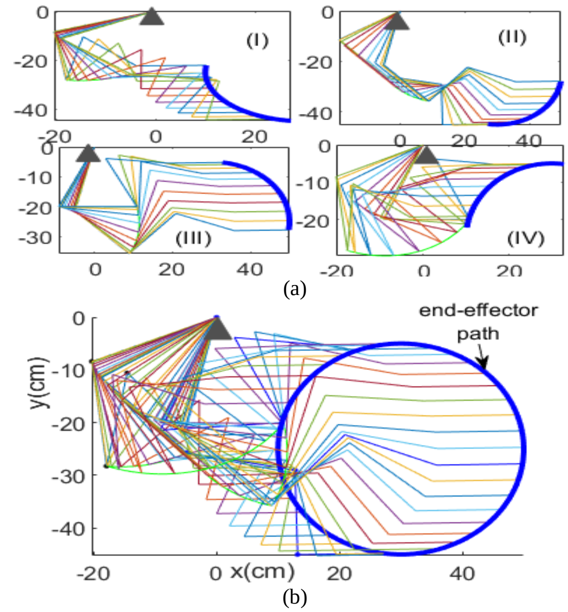


Fig. 8. Posture = $-\sqrt{1-c_2{}^2}$ (a) Each Stage (b) Overall Stage.

It can be observed that both possible postures do not contain any bad posture as when the path planning is conducted in one step path planning without the intermediate point (see Fig. 2b).

B. 12-DOF Planar Series Manipulator

This section studies the application of the proposed method to a 12-DOF planar series hyper-redundant manipulator. The manipulator has the same link length, 30 cm.

The desired end-effector path is a closed planar curve, namely a Japanese maple leaf which can be described in polar coordinate as follows:

$$\rho = k[(1 + \sin \Omega\, t)(1 + 0.3 \cos 8\, \Omega t)(1 + 0.1 \cos 2\, 4\Omega t)]$$

$$\Omega = \frac{2\pi}{T\_} \qquad (26)$$

where Ω and k are the angular frequency and scale factor, respectively.

This paper considers the joint angle constraint as follows:

$$0 \leq \theta_2 \leq \pi;\ 0 \leq \theta_5 \leq \pi;\ 0 \leq \theta_8 \leq \pi$$

$$0 \leq \theta_{11} \leq \pi \qquad (27)$$

For the hyper-redundant consists of only 3-link components, the first 3-link component, which has fixed base, should follow the first moving base. This first moving base become the base of the second 3-link component which should follow the second moving base. This mechanism is continued until the last 3-link component tracks the prescribed end-effector path. According to this scenario, for 12-DOF hyper-redundant manipulator, there are four local orientation angle boundaries. These boundaries represent the redundancy resolutions to track the desired end-effector path. The moving base is designed as the Lissajous curve with different parameter (see Table III).

TABLE III. MOVING BASE DEFINITION

Moving base	Curve	Search area
I	$x(t) = 12\,sin(2\Omega t) + 40$	[-0.4, 0.9]
	$y(t) = 12\,sin(\Omega t) + 30$	
II	$x(t) = 12\,sin(\Omega t) + 100$	[0, 0.7]
	$y(t) = 12\,sin(2\Omega t + {}^{\pi}/_{6}) + 70$	
III	$x(t) = 12\,sin(\Omega t) + 140$	[-1.6, -0.9]
	$(t) = 12\,sin(2\Omega t) + 10$	

There are three obstacles which have circular geometry with radius 10 cm. The positions of obstacles are (95, 15), (145, 65), and (40, -15). Due to the obstacles, the searching area of the first, second, and third 3-link components is reduced as described in Table III. For the fourth 3-link component, the searching area is [0.9, 1.6]. Because of the joint angle constraint, Eq. (27), only positive root of Eq. (8) are satisfied. Each joint angle trajectories of the 3-link component should be optimized with the detail results of the GA and the WOA presented in Table IV.

TABLE IV. PATH PLANNING RESULTS OF JAPANESE MAPLE LEAF CURVE PATH BY 12-DOF MANIPULATOR

3-link	GA		WOA	
	Fitness	***k***	***Fitness***	***k***
1	8.520017	-0.2964	8.520015	-0.2959
2	10.7813247	0.2857	10.7813234	0.2861
3	5.1071097	-1.3635	5.1071078	-1.3644
4	15.25502	1.4053	15.255025	1.4053

Fig. 9 illustrates the fitness evolution of the GA and WOA for each 3-link component. It shows that the WOA has outperformed the GA for the first, second, and third 3-link components where the WOA yield the lowest fitness value. For the fourth 3-link component, the GA and WOA yield the same optimal value.

Fig. 10 shows the joint angle trajectories for each 3-link component for m-cycle of curve. These joint angle trajectories are repeated every period time. It can be observed that the trajectories are periodic so that the proposed solution exhibits the cyclic properties. Fig. 11 shows the optimal posture of the hyper-redundant robot to track the Japanese maple leaf curve using the optimal k result obtain from WOA.

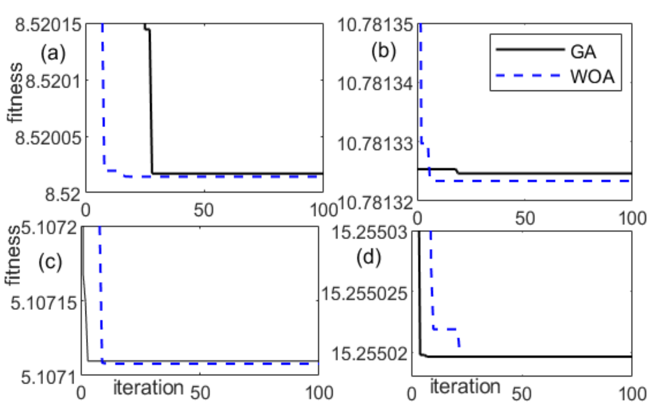


Fig. 9. Fitness Value Evolution of GA/ WOA of 3-Link Component (a) 1st (b)2nd (c) 3rd (d) 4th.

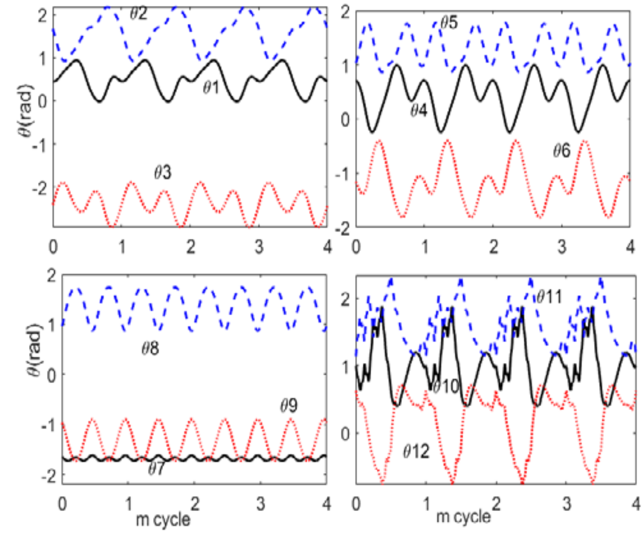


Fig. 10. Optimal Results of Joint Angles.

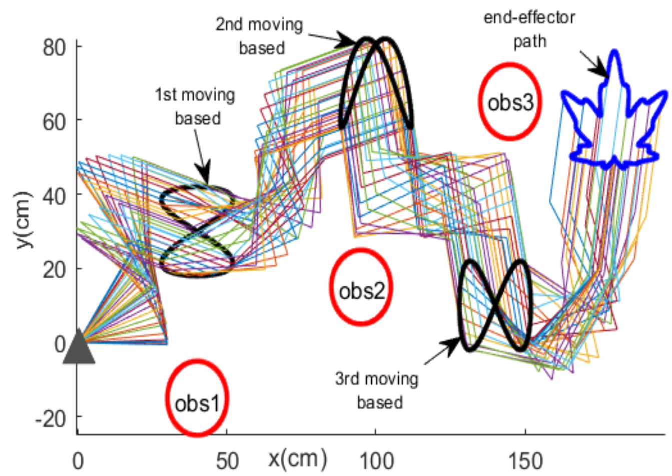


Fig. 11. Optimal Posture.

C. Comparison with Pseudoinverse Jacobian

The Jacobian-based method becomes the standard method to solve the IK of the hyper-redundant manipulator. This section investigates the performance of the Pseudoinverse Jacobian in solving the motion planning of the 12 DOF planar series manipulator presented in the previous sub-section.

Fig. 12 shows the joint angle trajectories and postures of the 12-link planar manipulator for 500-cycle of motion. The joint angle trajectories obtain by employing Pseudoinverse Jacobian with initial configurations are the same as starting configuration in the previous simulations. It shows that the continuous cyclic motion brings the generated trajectories beyond the joint angle constrains, Eq. (27). This situation should be avoided because it can trigger to the failure of the manipulator structures. This is very contrast with the results from the proposed approach where the generated trajectory has satisfied the cyclic property and the posture continuity as shown in Fig. 13. The robot movements also have clearly been observed very efficient movement and smooth as has been observed in Fig. 7, 8, 11.

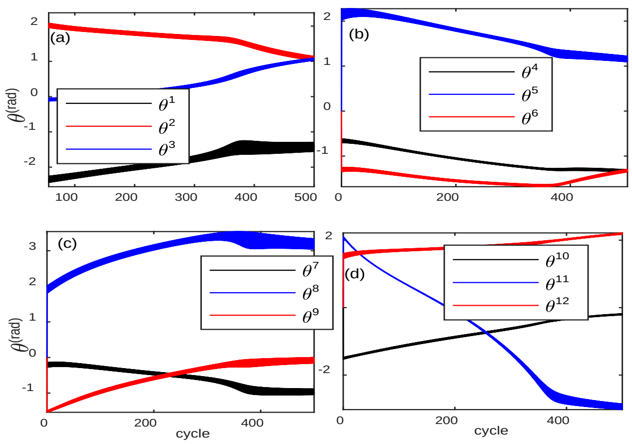
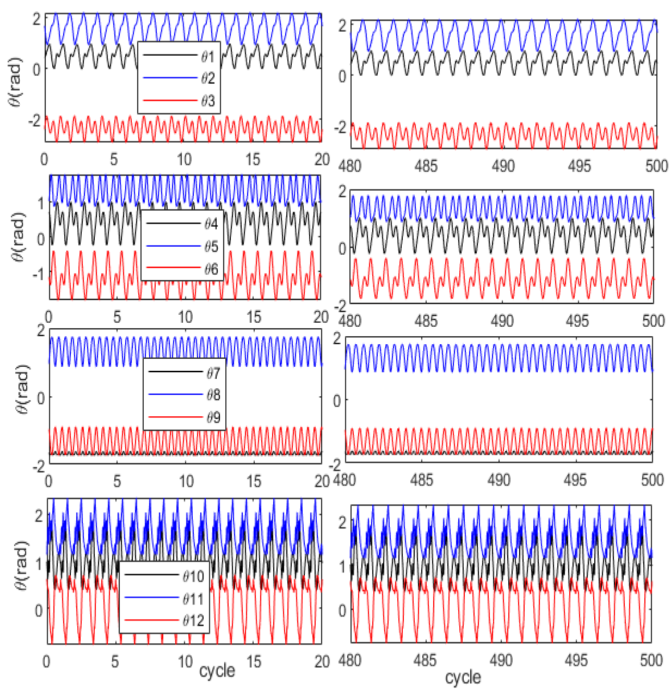


Fig. 12. Pseudoinverse Jacobian Generated Trajectories with 500-Cycle of Motion.



(a) (b)

Fig. 13. Proposed Method with 500-Cycle of Motion (a) 20 Earliest Cyclic Motions (b) 20 Latest Cyclic Motions.

These results indicate that achieving the cyclic behavior is a challenging computational problem and it needs a computational strategy. The proposed method is an alternative method for achieving the cyclic property for the hyper-redundant manipulator, instead of the Jacobian-based approach. The cyclic property is very essential because it guarantees the hyper-redundant motion lay within the safe zone, which is the operational area of the hyper-redundant manipulator.

Tracking the end-effector path by the hyper-redundant manipulator, there are many possible solutions. Using the Jacobian-based method, the results depend on the chosen initial configuration so that the exploration of the possible solutions to achieve the optimality is not possible. On the contrary, employing the meta-heuristic optimization, the possible solutions within the local orientation angle boundary have been explored and the optimal trajectories are founded successfully.

VI. Conclusion

The computational approach to achieve the cyclic properties of the hyper-redundant manipulator based on the geometrical approach optimized by the meta-heuristic optimization approach had been presented. It showed that the redundancy resolution can be mapped into the boundary of the local orientation angle of the 3-link component. Since the hyper-redundant was composed from many links, there were the moving base. The moving base can be obtained through either the additional path if the previous 3-link was available or by generating periodic joint angle trajectories having the same period with the end-effector curve if the previous component was 2-link. Depending on the path planning case, several intermediate points may be necessary to achieve the good posture. The presentation of the obstacle yielded reducing the feasible area of the searching parameter. The meta-heuristic optimization has been employed to choose the best solution among many possible solutions of the inverse kinematics. As compared to the Jacobian based method, namely, Pseudoinverse Jacobian, the proposed path planning yields not only the cyclic motion but also the optimal path. In general, the WOA had the best performance than that of the GA where during 100 iterations, the WOA obtained the lowest fitness value. The proposed path planning involves finding the optimal local orientation angle trajectories. For the future research, generating the 3-link component trajectories which yield the better solutions than the constant function can be conducted to improve the performance of the developed approach.

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Author's Contribution

A.M is the main contributor in this paper. S.P., A.A[3]., M.I.S., T.S.A.M., S.B., A.A[7]., N.W.R. are the supporting contributor.

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Deep Learning Predictive Model for Colon Cancer Patient using CNN-based Classification

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***Abstract*—In recent years, the area of Medicine and Healthcare has made significant advances with the assistance of computational technology. During this time, new diagnostic techniques were developed. Cancer is the world's second-largest cause of mortality, claiming the lives of one out of every six individuals. The colon cancer variation is the most frequent and lethal of the numerous kinds of cancer. Identifying the illness at an early stage, on the other hand, substantially increases the odds of survival. A cancer diagnosis may be automated by using the power of Artificial Intelligence (AI), allowing us to evaluate more cases in less time and at a lower cost. In this research, CNN models are employed to analyse imaging data of colon cells. For colon cell image classification, CNN with max pooling and average pooling layers and MobileNetV2 models are utilized. To determine the learning rate, the models are trained and evaluated at various Epochs. It's found that the accuracy of the max pooling and average pooling layers is 97.49% and 95.48%, respectively. And MobileNetV2 outperforms the other two models with the most remarkable accuracy of 99.67% with a data loss rate of 1.24.**

Keywords*—*Colon cancer; MobileNetV2; Max pooling; Average pooling; data loss; accuracy

I. Introduction

Cancer refers to a category of illnesses in which abnormal cells develop within the human body as a result of random mutations. When these cells are formed, they divide abnormally and spread throughout the organs. If left untreated, most cancers will eventually kill their victims. Fig. 1A, which shows the 4-tier Human Development Index (HDI) based on the UN's 2019 Human Development Report, shows how much cancer's position as a cause of early death corresponds with nation levels of social and economic development.

In rare situations, a person inherits from their parents the faulty gene that causes cancer. Regular checks are required for those who are at risk of getting hereditary malignancies. Many individuals cannot afford these diagnostic procedures since they are expensive. Cancer is responsible for over 70% of fatalities in poor and middle-income nations [1]. To meet this issue, countries must make significant investments in public health, establish a large number of labs and pathology centres with the requisite technology, and educate more people to perform diagnostic operations. Furthermore, keeping the costs of these examinations within reach of those who are poor is necessary. Finding new techniques for diagnosing cancer will give a genuine chance of survival.

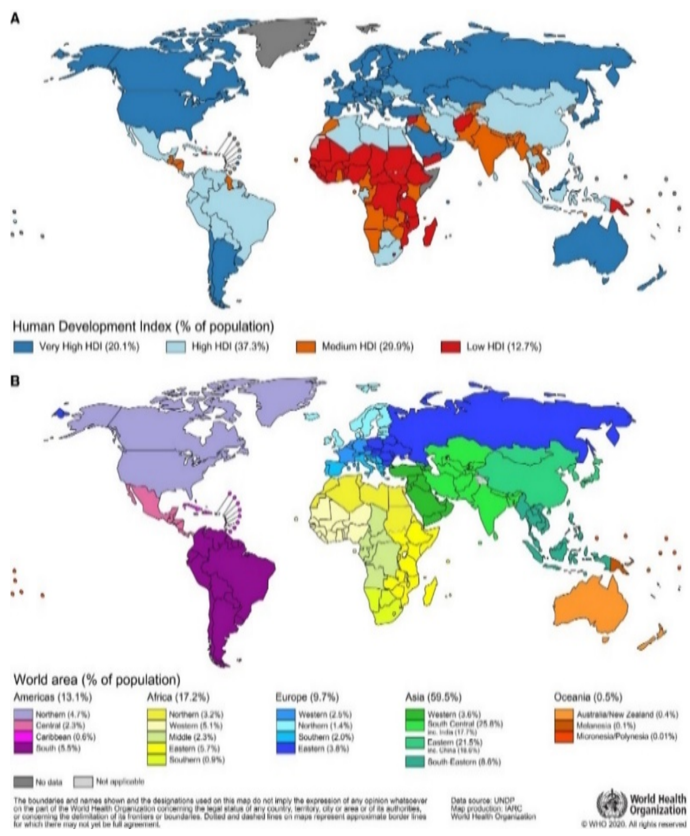

Fig. 1. (A) The Four-Tiered Human Development Index (HDI) and (B) the 20 World Regions. The Legend Includes the Population Sizes for Each Population. Source: United Nations Development Program/United Nations Procurement Division. Source: World Health Organization (WHO).

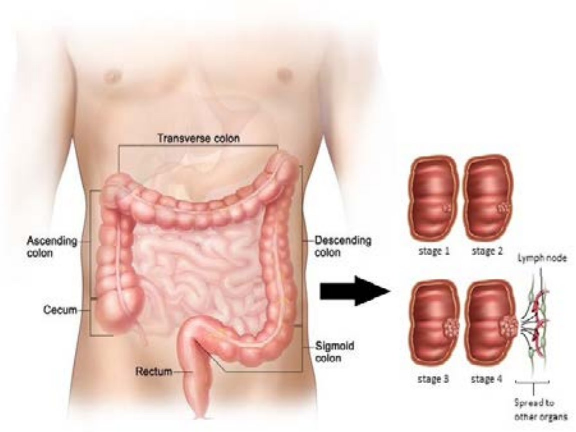

Fig. 2. Colon Cancer Polyps.

Most cancers have five stages, according to the Tumor-Node-Metastasis (TNM) classification devised and maintained by the American Joint Committee on Cancer (AJCC): 0, Stage I, Stage II, Stage III, and Stage IV [2]. The four stages of colon cancer are shown in Fig. 2. The approach considers a number of parameters, including the main tumor's size and location, the amount of its dissemination to lymph nodes and other organs, and the existence of any biomarkers that impact cancer spread. At certain phases, the odds of survival fluctuate dramatically. In the case of colon cancer, for example, more than 93% of persons between the ages of 18 and 65 may survive with effective treatment if they are discovered at Stage 0; however, survival rates at the later stages are 87%, 74%, and 18%, respectively [3]. The possibility of survival for colon cancer patients drops from 70% at Stage 0 to a terrifying 13% at Stage IV. As previously said, there is no sure therapy for cancer, thus the sooner a person is detected, the more time physicians have to design a treatment plan for the patients, the greater chance they get of surviving the condition. Early detection and early treatment are presently the only ways to prevent cancer-related fatalities [4]. However, most of the population lacks access to competent diagnostic facilities, making the fight against this deadly illness even more difficult.

In the field of diagnostics, AI has shown tremendous promise and provided us with a viable alternative to conventional diagnostic approaches. Currently, diagnosing an illness entails obtaining samples from a patient, executing a series of tests on those samples, putting the findings into an understandable format, and enlisting the help of a skilled expert to make judgments based on those findings. Now, if the samples taken from a patient are digital or have been digitalized somehow, machines can evaluate those. These data may then offer them a package of data comprising previous judgments on comparable circumstances. Finally, instructions are to be provided on how to detect the disorders that the new patient has. In machine learning, supervised learning refers to making judgments based on information obtained from past experiences. Different forms of biological signals have been classified and predicted using machine learning methods. Machines can now analyze high-dimensional data such as images, multidimensional anatomy images, and video thanks to the advent of Deep Learning (DL) algorithms. The learning algorithms inspired by the structure and function of the human brain are described in DL, a sub-field of ML [3]. DL uses artificial Neural Networks (ANNs) to improve pattern recognition skills. Above all, it is clear that AI has given the area of medical diagnostics a new dimension, and it is increasingly replacing old diagnostic procedures as a viable alternative [5 -7].

The rest of the paper is organized as follows. Section II provides a comprehensive summary of the many ML approaches utilized in colon cancer diagnosis. Section III provides an overview of the contents of the employed dataset and the method used for the classification purpose and techniques required to build this model. Moreover, it contains the criteria on which the performance of the model will be measured. Section IV elucidates the outcome of the model. Comparison of the result that different stages of the model's learning process are described in brief. Finally, Section V gives a summary of the work described in this article, along with some scopes of further research.

II. Related Work

In the past three decades, several supervised learning algorithms have been created, and they are quite good at dealing with biological data. Toraman et al. in [8] presented research aimed at classifying the probability of colon cancer using Fourier Transform Infrared (FTIR) spectroscopy signals. The authors collected various statistical characteristics from the signals and then used SVM and ANN to categorize them, yielding a classification accuracy of 95.71 % for ANN. Liping Jiao et al. [9] used the Gray-Level Cooccurrence Matrix (GLCM) method to extract eighteen ordinary characteristics, including grayscale mean, grayscale variance, and 16 texture features. On 60 colon tissue images partitioned evenly into the two groups, an SVM-based classifier obtained accuracy, F1-score, and recall of 96.67%, 83.33%, and 89.51%, respectively. S. Rathore et al. [10] developed a feature extraction method that mathematically mimics the geometric properties of colon tissue components. A hybrid feature set is created by combining conventional features such as morphological, texture, SIFT, and elliptic Fourier descriptors. SVM is then applied as a classifier on 174 colon biopsy pictures, with an accuracy of 98%. Yuan et al. [11] described a DL technique for automatically detecting polyps in colonoscopy films. The authors utilized AlexNet, a well-known CNN-based architecture, for classification, which resulted in a classification accuracy of 91.47 %. In [12], Babu et al. presented an RF-based classification algorithm for predicting the existence of colon cancer based on histological cancer images. First, the R-G-B images are transferred to the HSV plane. Then wavelet decomposition for feature selection is used to obtain a maximum classification accuracy of 85.4 % by varying the degree of image magnification. Mo et al. utilized a Faster R-CNN-based approach to identify colon cancer in [13]. The authors utilized a joint approximation optimization, which may optimize classification and regression losses simultaneously. In [14], Urban et al. developed a technique for detecting polyps in colonoscopy images with 96% classification accuracy. The authors hand-labeled 8641 colonoscopy images from 2000 individuals and used them to train a CNN model. They next tested their technique on 20 colonoscopy films totaling five hours in length. Akbari et al.

developed a CNN-based classification approach with binarized weights in [15] to detect colorectal cancer from colonoscopy films. The approach was tested using data from the Asu Mayo Test Clinic database and obtained over 90% classification accuracy. Masud et al. [16] inscribe a classification framework to distinguish colon tissues (two benign and three malignant) by evaluating their histological pictures using CNN and Digital Image Processing (DIP) methods. The obtained findings indicate that the proposed framework can detect cancer tissues with an accuracy of up to 96.33 %. Garg et al. in [17] used and modify an existing pre-trained CNN-based model to detect lung and colon cancer using histopathology pictures and improved augmentation methods. On the LC25000 dataset, eight different Pre-trained CNN models, VGG16, NASNetMobile, InceptionV3, InceptionResNetV2, ResNet50, Xception, MobileNet, and DenseNet169, are trained. Precision, recall, f1-score, accuracy score are used to evaluate model performance. The findings show that all eight models achieved notable outcomes ranging from 96% to 100% accuracy.

In the proposed study, authors tested image data for colon cells obtained from online data sources to detect colon cancer. They are using the Transfer learning model MobileNetV2. The process contains two CNN layers, Max Pooling, and average pooling. The image data goes through a number of preprocessing steps to give a better classification outcome. The performance of the model is evaluated based on the confusion matrix.

III. Methodology

Image data of colon cells were used in the proposed method to detect colon cancer. The images are then labeled in order to determine which cells cause cancer. The prediction is made using the MobileNetV2 classifier. Fig. 3 illustrates the system's total flow diagram.

A. Data Description

Kaggle.com was used to gather the dataset. There are 25000 images in the dataset. The images are 768 x 768 pixels in resolution and JPEG format. In the dataset, there are two classes, i.e.

1) Colon adenocarcinoma (cancerous).
2) Colon benign tissue (not cancerous).

Of all the images in the dataset, 12,500 images are of colon cancer cells, as shown in Fig. 4(a, b). Fig. 4(c, d) shows the sample of the rest of the cell images without colon cancer.

B. Environment Setup

Tensorflow and the Keras library were used to carry out this analysis. Tensorflow is a free, open-source Python library for performing large-scale machine learning calculations. Tensorflow is used extensively in artificial neural networks and is used in Keras' backend.

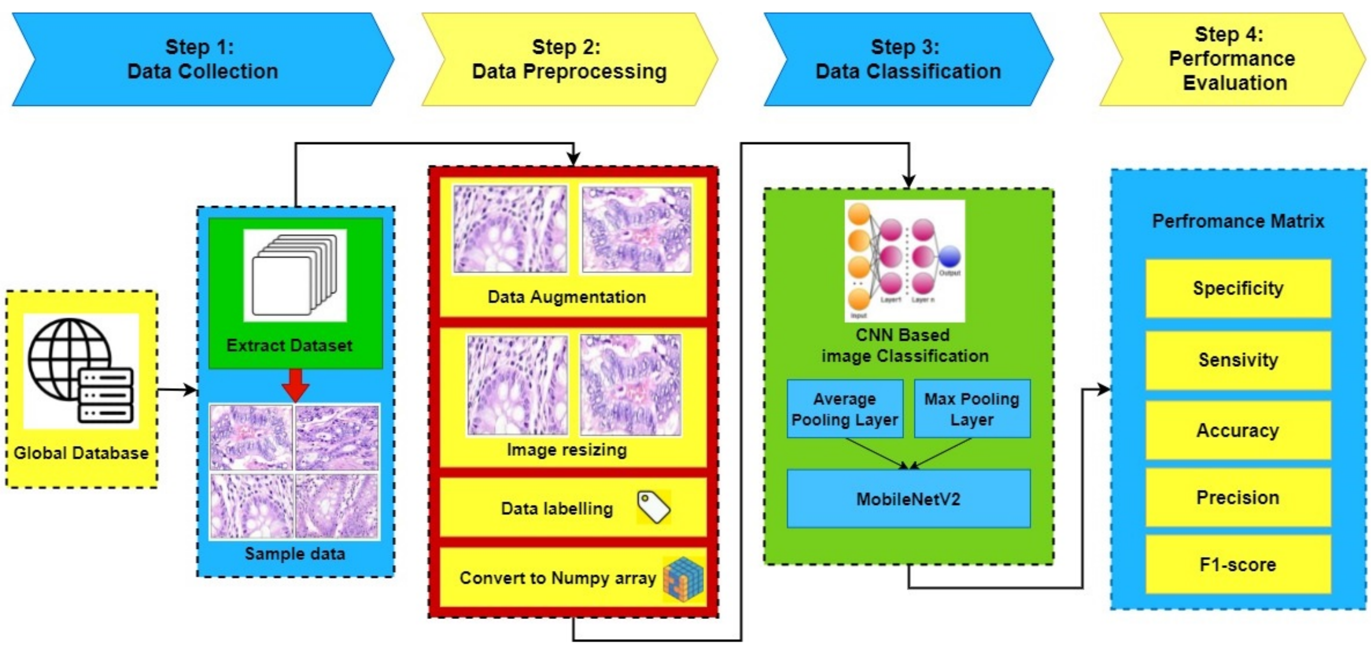

Fig. 3. Proposed Model Processed Diagram.

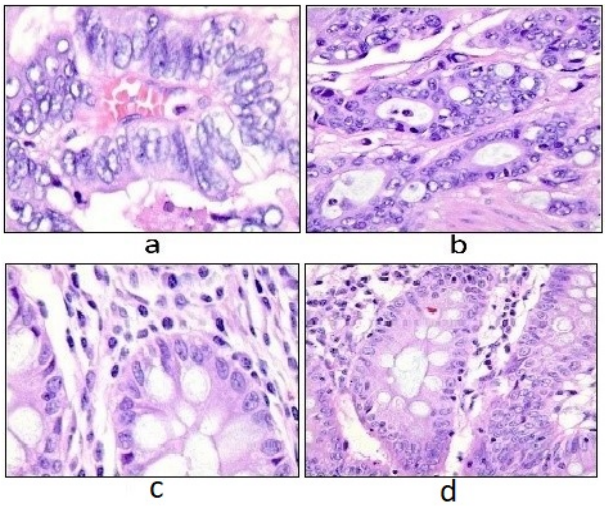

Fig. 4. Sample Images of (a, b) Colon Cancer Cells, (c,d) Healthy Colon Cells.

C. Data Preprocessing

To make sure the image data are fit to be used to train and test the classifier, preprocessing is done. Raw data has to be preprocessing according to the use of the study. Following are:

- To expand the volume of the dataset, ImageDataGenerator class in Keras library is used to create augmented images using the attributes in Table I.

TABLE I. IMAGEDATAGENERATOR ATTRIBUTES

Rotation Range	20
Zoom_Range	0.15
Width_Range	0.2
Height_Range	0.2
Shear_Range	0.15
Horizontal_Flip	True
Vertical_Flip	True
Mode	Nearest

- Images resized to 224 X 224 pixels.
- LabelBinarizer() is used to assign unique values to each label in categorical features.
- The image data is converted to a NumPy array.

D. CNN Classifier

CNN is an example of a Deep Learning algorithm that takes an input image and assigns priority to different aspects of the image, allowing it to distinguish one image from another based on its features. In this system, two convolutional layers in the CNN model are used where each convolutional layer used convolutional 2D. In both convolutional 2D layers, 'Relu activation' is utilized. For complete connectivity, two Dense Layers are used. 'Relu activation' for the first dense layer and 'Sigmoid activation' for the second dense layer is used. Aside from these layers, there are several hidden layers, as well as an input layer. In this study, two pooling layers: Max Pooling 2D and Average Pooling 2D, are implemented [18]. Finally, for the classification of image data MobileNetV2 classifier is used.

1) Max pooling layer: It is a pooling operation that selects the maximum element from the feature map area covered by the filter. By decreasing the number of pixels in the output, max-pooling lowers the dimensionality of pictures [19]. The following Fig. 5 is our study model based on the Max pooling Layer:

2) Average pooling layer: It is a pooling operation that selects the average element from the filter's covered area of the feature map. Average pooling counts all values and passes them on to the next layer, implying that all values are utilized for feature mapping and output generation, which is a comprehensive calculation [20]. Fig. 6 is our study model, which is based on the Average Pooling Layer.

3) MobileNetV2 classifier: MobileNetV2 model has 32 filters on its initial fully convolution layer. There are 19 bottleneck layers that remain. It is used in the classification of images [21]. MobileNetV2 introduces two new kinds of blocks.

i. Downsizing block of 2 stride.
ii. Residual block of stride 1.

All blocks are made up of three layers. With 1X1 convolution, the ReLU6 activation mechanism is used in the first layer. On the second sheet, a depth wise is added, and the third layer is also a 1X1 convolution, except for some non-linearity. The activation mechanism of ReLu is often included in the third layer. The architecture of the model is illustrated in Fig. 7.

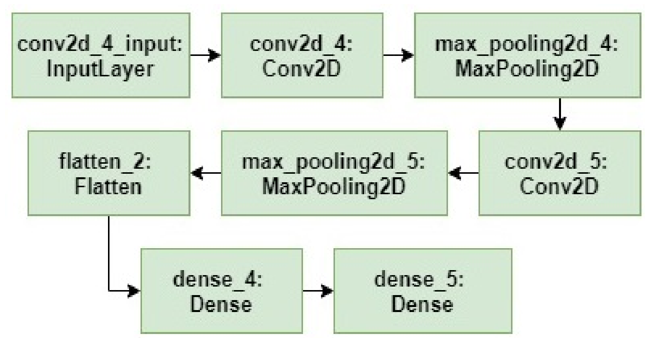

Fig. 5. Two Convolution Layer with Max Pooling Action.

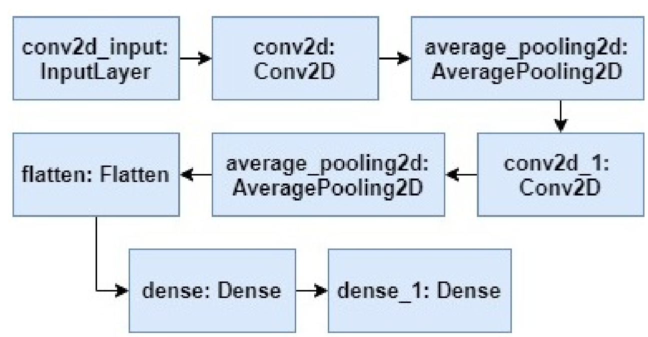

Fig. 6. Two Convolution Layer with Average Pooling Action.

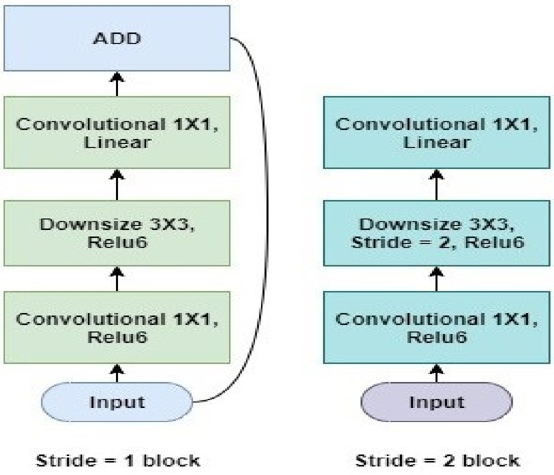

Fig. 7. MobileNetV2 Architecture.

E. Performance Evaluation

After the training and testing process, the performance is evaluated using specificity, recall, precision, accuracy and f1-score. Eq. 1, 2, 3, 4 and 5 are the equations used for the task.

$$\text{Specificity} = \frac{\text{TN}}{\text{TN + FP}} \tag{1}$$

$$\text{Sensitivity or recall} = \frac{\text{TP}}{\text{TP+ FN}} \tag{2}$$

$$\text{Precision} = \frac{\text{TP}}{\text{TP+ FP}} \tag{3}$$

$$\text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+FP+TN+FN}} \tag{4}$$

$$\text{F1} - \text{score} = 2 \times \frac{precision \times recall}{precision + recall} \tag{5}$$

Here, the true positive (TP), true negative (TN), false positive (FP), false negative (FN) are obtained from the confusion matrix in Fig. 8.

	Predicted 0	Predicted 1
Actual 0	TN	FP
Actual 1	FN	TP

Fig. 8. Confusion Matrix.

IV. Experimental Result and Analysis

A. Outcome of Max Pooling Layer

The training set contains 80% of the data from the dataset and the rest 20% is in the test set. During the process of data classification, 94.44% accuracy is obtained in the training data set and 97.49% accuracy in the testing data set is obtained as shown in Table II at the max pooling layer.

The accuracy of the max pooling model gradually increases as the number of epochs increase as shown in Fig. 9. The training set reaches the highest accuracy at epoch 49, whereas the test set has the highest accuracy at epoch 46.

TABLE II. Accuracy of Outcomes in Max Pooling Layer for Different Epochs

Epoch	Training Loss	Training Accuracy	Test data Loss	Test Accuracy
1	1.7743	0.5232	0.6825	0.5276
2	0.6733	0.5338	0.6610	0.5528
3	0.6535	0.5603	0.8085	0.5126
4	0.6317	0.6066	0.6061	0.6884
5	0.6292	0.6066	0.5827	0.6482
6	0.5984	0.6583	0.5451	0.7538
7	0.6000	0.6609	0.5580	0.7136
8	0.5875	0.6808	0.5037	0.7789
9	0.5531	0.6781	0.4449	0.8141
10	0.5364	0.7205	0.4406	0.8342
11	0.5450	0.7325	0.3826	0.8241
12	0.5221	0.7364	0.3723	0.8442
13	0.5113	0.7457	0.4109	0.8442
14	0.4927	0.7457	0.3840	0.8291
15	0.4860	0.7616	0.3745	0.8342
16	0.7510	0.7510	0.3551	0.8693
17	0.4967	0.7536	0.3428	0.8392
18	0.4662	0.7656	0.3323	0.8392
19	0.4205	0.7960	0.3235	0.8593
20	0.4362	0.7775	0.2994	0.8995
21	0.4114	0.8106	0.2682	0.8744
22	0.4127	0.8013	0.2726	0.8693
23	0.3863	0.8066	0.3230	0.8191
24	0.3425	0.8464	0.2279	0.8995
25	0.3594	0.8278	0.2297	0.9095
26	0.3644	0.8397	0.2388	0.8894
27	0.3101	0.8742	0.2190	0.9196
28	0.3074	0.8596	0.2089	0.9146
29	0.3329	0.8583	0.2119	0.9146
30	0.3069	0.8570	0.2064	0.9246
31	0.3153	0.8583	0.2890	0.8794
32	0.2862	0.8675	0.1678	0.9497
33	0.2834	0.8768	0.2158	0.8995
34	0.2698	0.8861	0.2034	0.9296
35	0.2902	0.8861	0.1936	0.9347
36	0.2554	0.8940	0.1924	0.9296
37	0.2363	0.8993	0.3039	0.8995
38	0.2246	0.9099	0.1353	0.9397
39	0.2312	0.9086	0.1523	0.9648
40	0.2290	0.8887	0.1172	0.9598
41	0.2334	0.9086	0.1160	0.9497
42	0.2321	0.9020	0.1153	0.9749
43	0.2002	0.9033	0.1717	0.9397
44	0.2028	0.9192	0.0879	0.9749
45	0.2091	0.9192	0.1232	0.9648
46	0.1759	0.9272	0.0756	0.9749
47	0.1881	0.9245	0.0874	0.9648
48	0.1636	0.9311	0.0718	0.9598
49	0.1634	0.9444	0.0968	0.9548
50	0.1898	0.9245	0.0802	0.9648

The data loss of the model in the training and testing dataset decreases rapidly with the number of epochs as illustrated in Fig. 10. The lowest data loss is found at epoch 48 for both training and test set.

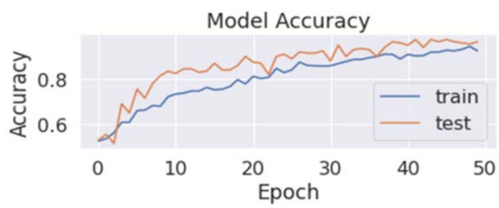

Fig. 9. Test Accuracy and Training Accuracy for Max Pooling Layer at Different Epochs.

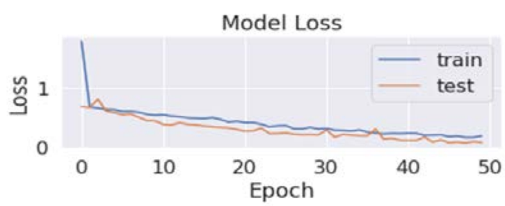

Fig. 10. Test Loss and Training Loss with Max Pooling Layer at Different Epochs.

1) MSE (Mean Square Error) and AUC: The following MSE and AUC applying on the test data set using Max Pooling Layer are achieved:

- MSE (Mean Square Error) of 0.0286 (Fig. 11)
- AUC of 0.9932 (Fig. 12)

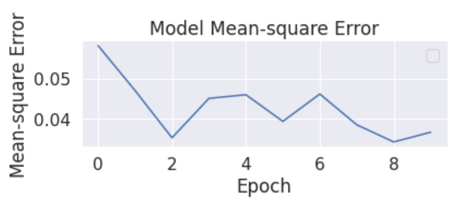

Fig. 11. Test Mean-Square Error for Max Pooling Layer at Different Epochs.

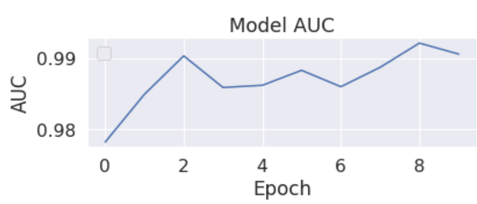

Fig. 12. Test AUC with Max Pooling Layer at Different Epochs.

B. Confusion Matrix using Max Pooling Layer

Using 3000 image data, the confusion matrix is created for max-pooling layer. The outcome of the matrix is as follow:

- True positives (TP): 1745.0000
- True negatives (TN): 1217.0000
- False positives (FP): 27.0000
- False negatives (FN): 11.0000
- Sensitivity or Recall= 0.993=99.3%
- Specificity= 0.9782=97.82%
- Precision= 0.983=98.3%

C. Outcome of Average Pooling Layer

In the average pooling model, the accuracy of 90.73% in the training data set and 95.48% in the testing data set was achieved. The record of the outcomes of all the epochs is shown in Table III.

TABLE III. ACCURACY OF OUTCOMES IN AVERAGE POOLING LAYER FOR DIFFERENT EPOCHS

Epoch	Training Data Loss	Training Accuracy	Test Data Loss	Test Accuracy
1	2.0488	0.4795	0.6844	0.5075
2	0.6634	0.5152	0.6586	0.6382
3	0.6527	0.5854	0.6430	0.6181
4	0.6385	0.6159	0.6071	0.6935
5	0.6142	0.6477	0.5732	0.6884
6	0.5987	0.6821	0.6038	0.6884
7	0.5900	0.6834	0.5728	0.6985
8	0.5963	0.6609	0.4985	0.7588
9	0.5634	0.7020	0.4718	0.7990
10	0.5741	0.6821	0.4919	0.7789
11	0.5394	0.7192	0.4575	0.8141
12	0.5317	0.7311	0.4708	0.8291
13	0.5251	0.7272	0.3687	0.8744
14	0.5115	0.7444	0.4035	0.8191
15	0.5464	0.6980	0.4161	0.8442
16	0.5239	0.7457	0.3710	0.8593
17	0.4736	0.7470	0.3436	0.8392
18	0.4686	0.7722	0.4097	0.8040
19	0.4716	0.7589	0.2913	0.8693
20	0.4791	0.7656	0.2726	0.8945
21	0.4162	0.7907	0.2840	0.8794
22	0.4244	0.7974	0.2986	0.8794
23	0.4024	0.7881	0.4226	0.7940
24	0.4428	0.7868	0.2846	0.8995
25	0.4118	0.8000	0.2934	0.8643
26	0.4088	0.8119	0.2507	0.8894
27	0.3700	0.8318	0.2775	0.8945
28	0.3424	0.8411	0.2778	0.8794
29	0.3418	0.8490	0.2186	0.8794
30	0.3194	0.8583	0.2455	0.8744
31	0.3585	0.8331	0.3152	0.8543
32	0.3567	0.8503	0.2626	0.8744
33	0.3227	0.8636	0.2387	0.8995
34	0.3196	0.8649	0.2223	0.9095
35	0.3223	0.8596	0.2035	0.9146
36	0.3078	0.8662	0.2163	0.9196
37	0.3071	0.8768	0.2536	0.8794
38	0.3086	0.8781	0.2009	0.9397
39	0.2727	0.8834	0.1955	0.9347
40	0.2848	0.8887	0.2586	0.8794
41	0.3037	0.8728	0.1925	0.9045
42	0.2903	0.8795	0.2803	0.8794
43	0.2860	0.8781	0.1715	0.9347
44	0.3110	0.8768	0.1637	0.9397
45	0.2678	0.8980	0.1365	0.9548
46	0.2254	0.9073	0.1471	0.9397
47	0.2393	0.8954	0.1299	0.9497
48	0.2263	0.8967	0.1527	0.9447
49	0.2442	0.8887	0.1942	0.9146
50	0.2169	0.9046	0.1492	0.9296

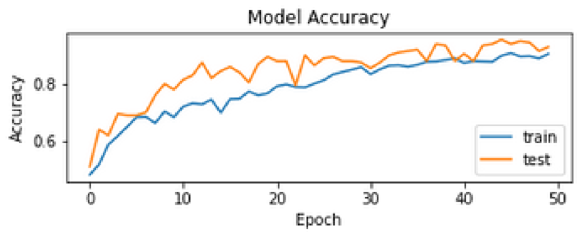

Fig. 13. Test Accuracy and Training Accuracy in Average Pooling Layer for Different Epochs.

As shown in Fig. 13, the accuracy of the average pooling model progressively improves as the number of epochs grows. The highest accuracy for the test set is in the 46th epoch and the training set is in the 45th epoch.

The model's data loss in the training and testing datasets reduces quickly with the number of epochs, as seen in Fig. 14 for the average pooling layer.

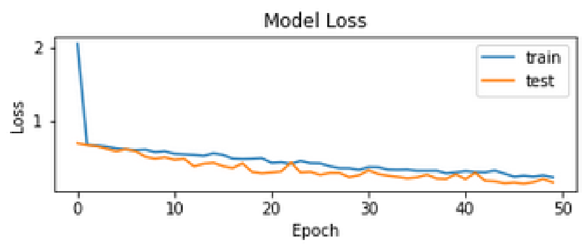

Fig. 14. Test and Training Data Loss in Average Pooling Layer For Different Epochs.

D. MSE (Mean Square Error) and AUC

The following MSE and AUC were achieved by applying the test data set on the Average Pooling Layer:

- MSE (Mean Square Error) of 0.0588 (Fig. 15)
- AUC of 0.9753 (Fig. 16)

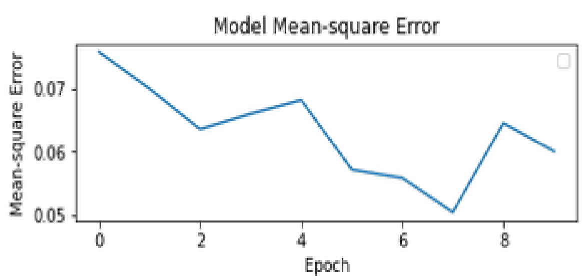

Fig. 15. Test Mean-Square Error in Average Pooling Layer.

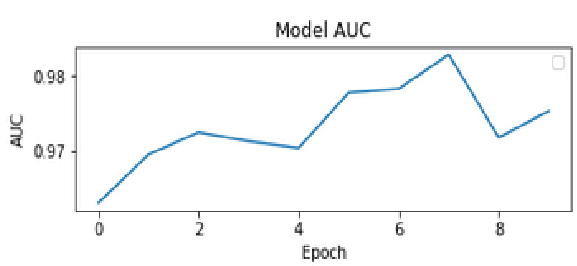

Fig. 16. Test AUC in Average Pooling Layer.

E. Confusion Matrix using Average Pooling Layer

The confusion matrix for the average pooling layer is built using 2500 image data. The confusion matrix produced the following results:

- True positives (TP): 14105.0000
- True negatives (TN): 9851.0000
- False positives (FP): 466.0000
- False negatives (FN): 578.00
- Sensitivity or Recall = 0.9606 = 96.06%
- Specificity = 0.9548 = 95.48%
- Precision = 0.9702 = 97.02%
- F1-Score = 0.9657 = 96.57%

F. Classification Outcome of MobileNetV2 Model

After loading the MobileNetV2 model, the top layer is frozen and the weights from ImageNet are loaded. A custom model is placed there, and the architecture is trained. The AveragePooling2D operation is included in the model, and the pool size is (7, 7). There is a 128-node hidden layer, and the ReLU activation function is used to remove features correctly. Because deep learning models are prone to overfitting, dropout is used to select training images at random. All of MobileNetV2's trainable layers are no longer used. The Adam optimizer feature is used to better learn models from errors. By setting the trainable layer parameter to False, the base layers of all transfer learning models were frozen. A customize trainable layer consisting of one hidden layer with 128 neurons was introduced at this stage. The Average Pooling operation was applied where the pool size is (7,7). The process is shown in Fig. 17.

For the back-propagation process, the learning rate is set to 0.01. Binary cross-entropy is used to calculate the loss function. SoftMax activation is included in the output layer and is more accurate than other activation functions. Table IV displays the training and test accuracy, as well as the data loss rate.

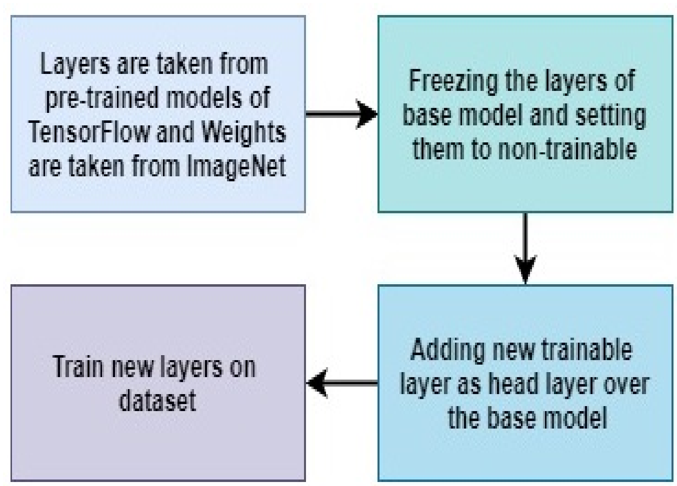

Fig. 17. Execution of MobileNetV2.

TABLE IV. TRAINING AND TSET ACCURACY WITH DATA LOSS OF MOBILENETV2

Epoch Number	Training Data Loss %	Training Accuracy in %	Tset Data Loss in %	Test Accuracy
1	35.95	97.54	39.34	83.11
2	7.50	98.24	6.61	98.18
3	2.91	98.69	4.44	98.79
4	4.87	98.76	5.46	98.49
5	3.25	98.79	5.78	98.11
6	4.38	98.30	2.66	99.33
7	3.53	98.86	3.11	98.87
8	3.33	99.19	2.76	99.29
9	2.75	99.13	4.05	98.83
10	2.06	99.57	3.69	98.94
11	1.77	99.62	5.17	98.14
12	1.72	99.72	3.73	98.98
13	1.74	99.65	3.20	98.79
14	1.54	99.73	1.60	99.50
15	1.46	99.81	1.70	99.67
16	2.43	99.12	3.34	99.19
17	2.34	99.25	2.85	98.82
18	2.40	99.20	2.47	99.17
19	2.63	99.18	1.99	99.23
20	3.76	98.60	1.24	99.60

Maximum training accuracy is 99.81%, and the minimum data loss is 1.46% in epoch 15 for the training set. The overall accuracy of the model is consistently high the data loss is consistently low for the Training data, as shown in Fig. 18 and 19.

As deep learning models learn faster with experience, data loss decreases as the number of epochs increases. The data loss at epoch 15 is 1.7% and the accuracy is 99.67% test set. The gradual decrease of data loss and gain of accuracy is illustrated in Fig. 20 and 21, respectively.

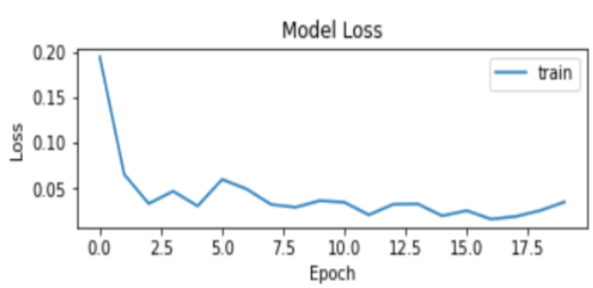

Fig. 18. Data Loss Curve for Training Data.

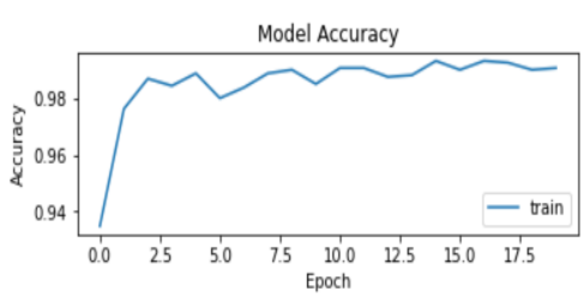

Fig. 19. Accuracy Curve for Training Data.

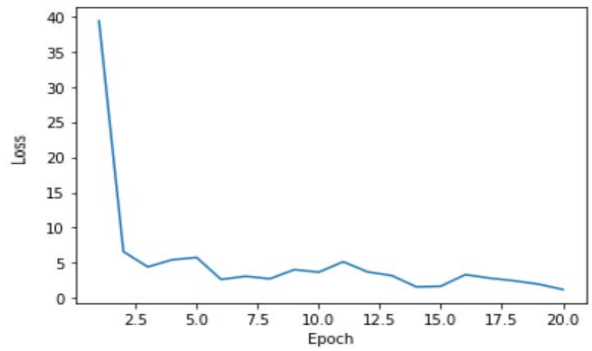

Fig. 20. Data Loss Curve for Test Data.

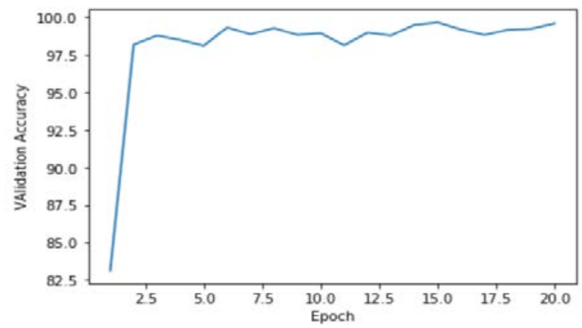

Fig. 21. Test Set Accuracy.

The confusion matrix was used to assess results, and the outcome represents the model's high accuracy on this dataset. The performance calculation is demonstrated in Fig. 22.

```
              precision    recall  f1-score   support

   colon_aca       0.99      1.00      1.00       201
     colon_n       1.00      0.99      0.99       199

    accuracy                           0.99       400
   macro avg       1.00      0.99      0.99       400
weighted avg       1.00      0.99      0.99       400
```

Fig. 22. Classification Performance of MobileNetV2.

Table V compares the findings obtained from the suggested techniques of colon cancer cell categorization approaches. Image data were utilized in the study's training and testing purposes. MobileNetv2 outperforms the other two models (Max pooling and Average pooling) in terms of performance. Based on the talks in this part, it is possible to infer that the suggested models can perform the job of colon cancer tissue categorization with excellent accuracy and reliability.

TABLE V. RESULTS OBTAINED FROM THE METHODS

Model Name	Training Accuracy	Training Data Loss	Test Accuracy	Test Data Loss
Max Pooling	94.44%	0.1634	97.49%	0.0756
Average Pooling	90.73%	0.2254	95.48%	0.1365
MobileNetV2	99.81%,	1.46	99.6%	1.24

V. Comparative Analysis

As previously stated (Section II), many research have been conducted to predict colon cancer using machine learning, deep learning, and other methods based on various imaging data of cancer cells. The Table VI below compares several methods utilized by researchers on different datasets with the proposed method. Despite earlier research shown great accuracy in predicting colon, the suggested approach outperformed the prediction accuracy.

Though earlier work on the prediction of colon cancer cell has excellent accuracy, it is limited to models built on smaller datasets. In the final prediction stage, the suggested model outperformed the previously described studies. Furthermore, the models in the research are trained and tested on a larger dataset making it more efficient and reliable.

TABLE VI. Comparison of Previous Methods and the Proposed Method

Studies	Datasets	Models	Accuracy
Proposed study	12,500 images of colon cancer cells from kaggle	Max pooling	97.49%
		Average pooling	95.48%
		MobileNetV2	99.67%
Toraman et al. [8]	samples of 30 colon cancer patients and 40 healthy subjects were obtained from the Department of General Surgery of Fırat University	ANN	95.71%
Urban et al. [14]	• ImageNet data set • 8641 colonoscopy images • 1330 colonoscopy images from different patients. • colonoscopy first set of 9 videos • Augmented dataset • Colonoscopy second set of 11 videos	VGG19	96.4 ± 0.3%
Masud et al. [16]	LC25000 dataset	employed CNN	96.33%
Rathore et al. [22]	174 colon biopsy images	hybrid feature space based colon classification (HFS-CC)	99.18%
Hamida et al. [23]	CRC-5000 dataset	SEGNET	98.66%
Liang et al. [24]	Hematoxylin and Eosin (H&E) stained human colon tissue histopathology image	MFF-CNN based on shearlet transform	96%

VI. Conclusion

In recent years, machine learning and deep learning have had a significant impact on image processing, the medical industry, and a variety of other applications. The proposed approach takes around a minute to identify colon cancer from the input pictures. The goal of the study is to make this procedure as easy, quick, and real-time as feasible. The dataset utilized for training and testing includes both cancer cells and healthy cells. Enhanced images were added to the dataset. In this work, the CNN algorithm with max and average pooling layers, as well as a transfer learning MobileNetV2 model, are used to identify colon cancer. It is observed that the CNN-based Max Pooling and Average Pooling operations have high accuracy of 97.49% and 95.48%, respectively and the MobileNetV2 model has a high accuracy rate of 99.67%. In future work, the model can be trained and tested using a more extensive dataset at the same time this model can be tested on other cancer datasets for classification and prediction. The study would be cooperated with medical researchers in hospitals or clinics that handle colon cancer work in the future, which would be beneficial for further application of this work in the medical sector.

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Towards Indian Sign Language Sentence Recognition using INSIGNVID: Indian Sign Language Video Dataset

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***Abstract*—Sign language, a language used by Deaf community, is a fully visual language with its own grammar. The Deaf people find it very difficult to express their feelings to the other people, since the other people lack the knowledge of the sign language used by the Deaf community. Due to the differences in vocabulary and grammar of the sign languages, complete adoption of methods used for other international sign languages is not possible for Indian Sign Language (ISL) recognition. It is difficult to handle continuous sign language sentence recognition and translation into text as no large video dataset for ISL sentences is available. INSIGNVID - the first Indian Sign Language video dataset has been proposed and with this dataset as input, a novel approach is presented that converts video of ISL sentence in appropriate English sentence using transfer learning. The proposed approach gives promising results on our dataset with MobilNetV2 as pretrained model.**

Keywords—Indian sign language; sign language recognition; pretrained models; transfer learning; vision-based approaches

I. Introduction

Sign language is primary language for Deaf people to communicate with each other as well as with hearing people. One common perception exists which says that though deaf students use sign language as their main language, it is difficult for them to read texts fluently in their country's home language because their vision isn't hindered. But the fact is that signers learn their country's language as a secondary language, and so they cannot read and write texts fluently. For example, an English sentence *I don't understand* in sign language can be *I understand no*. If a person's primary language is sign language, all the other words are seen as noise which makes writing and comprehension in other language harder for him [1].

Therefore, communication in sign language becomes natural and easy way for Deaf. However, understanding sign language is difficult for hearing person, that is why human interpreters are required in emergency situations. They provide interpreting service that is easy-to-use but it has major limitations because India has only around 300 certified interpreters [2]. Because of the small number of human interpreters, interpretation service is not always available in urgent situations, training sessions and educational systems. Another service which became popular in last decade is online interpretation services, but this service is highly dependent on Internet connections from human interpreter and signer's end. Moreover, this service is also dependent on availability of human interpreters.

Given a recognized shortage of interpreters, an effective way of communication system should be developed that bridges the gap between signers and hearing people. The hearing person thus will easily understand the message that a Deaf want to convey. Such an approach should be the best alternative to the human interpreter in case of emergency situations or even to access the services in local community. The system should be designed in such a way that it should also improve quality of life for Deaf community.

The main dimensions of research in automatic sign language recognition are grouped as: Recognition of Isolated signs and recognition of continuous sign. In isolated sign recognition, static or dynamic single signs are recognized without continuation of any other sign. Isolated sign is not affected by the previous or following sign. In continuous sign language recognition system, different signs are performed one after another to recognize complete sign language word or sentence. Considering sign languages at international level, many differences exist among them. The same datasets and methods cannot be used for Indian Sign Language (ISL) recognition due to the very few meaningful similarities in grammar and vocabulary of all the sign languages [3-5]. In India, major research is focused on regional versions or manual components of signs. [6-11] reported work on dynamic hand gesture recognition for their dataset having limited number of gestures for single and two-hands manual signs. For Indian sign language translation, [12] and [13] proposed algorithms to convert ISL sentences in English text but they used traditional rule-based approach for sign translation due to limited size of their datasets. Also, the existing datasets are not prepared according to dictionary released by Indian Sign Language Research and Training Centre (ISLRTC).

Compared to other international sign languages, Indian sign language recognition and translation is still in inception. Device or sensor-based and vision-based approaches have been used for recognizing sign language from images of sign. Vision-based approach is better than device-based methods as device-based methods need extended setup and they also limit the inherent movement of the face and hands.

If we see sign language recognition as image recognition problem, deep neural networks perform exceptionally well for such tasks [14]. But these networks are largely dependent on huge data to avoid problem of overfitting. Overfitting refers to the phenomenon when a network learns a function with very high variance such as to perfectly model the training data [2]. One of the ways for dealing with the problem of limited dataset size is called data augmentation [15]. This approach can be used on input videos for Indian sign language recognition to make dataset inflated.

In this article, one research question has been addressed in particular: how to use deep neural network with very small amount of input videos in order to incorporate both left-handed and right-handed signs without hurting recognition performance of ISL sentences. A dataset – INSIGNVID is also created, which is the first ISL video dataset that uses official ISL signs released by ISLRTC. On this dataset all steps of proposed approach are performed and promising results are shown using MobileNetV2 pretrained model. This article is organized as follows: Brief literature review of existing ISL recognition systems is discussed in Section 2. Detailed description of dataset-INSIGNVID is given in Section 3. This dataset is created to motivate research in field of ISL dynamic gesture recognition. Section 4 discusses steps of the proposed approach with detailed explanation. Section 5 describes implementation scenario and results of ISL gesture recognition using proposed approach. Section 6 provides concluding remarks and directions for future work.

II. Related Work

Considering sign language recognition, two types of different approaches exist: (i) Sensor or glove-based approach and (ii) Vision based approach. Sensor based methods have advantage of extracting the signer’s movements and postures more accurately because they use specialized gloves, which are embedded with several sensors to capture the sign information. There is a significant amount of work reported in ISL recognition giving good accuracy with different methods using sensors, and a thorough review is presented in [16]. However, it is practically impossible to wear the gloves by signers in their daily activities as they restrict the movement of signers. Also, in the emergency situations, this setup may not be available with signer. Vision based approach on the other hand, is cost effective and flexible solution while touch based approach is complex, costly and difficult to deploy [17].

By taking different international sign language recognition systems into account, many standard datasets are available publicly. The author in [18] proposed RWTH-PHOENIX-Weather video dataset, for Germen sign language recognition, translation and pattern recognition. The same dataset was extended by [19], which has tripled the original dataset in size. Both of these datasets contain sign languages of news related to weather forecasting. SIGNUM dataset [20] was used for German sign language recognition to handle multiple signers through statistical approach. [21] formulated Bayesian network to recognize Boston American sign language using videos of American sign language lexicon video dataset (ASLLVD). Polish sign language word dataset – PSL Kinect 30 was created with Microsoft Kinect and was used by [22] with skin color-based features. The authors also performed the same experiments on another Polish sign language dataset – PSL ToF 84 and discussed the results on both of these datasets. [23] have proposed a pre-processed version of an Argentinian sign language dataset – LSA64 to promote research in Argentinian sign languages. Human action recognition using depth sequences of MSR Gesture 3D – American sign language was implemented by [24] using gradient features.

A significant amount of research is done on static sign recognition for ISL. The authors in [25-30] have proposed approaches for isolated ISL recognition. Microsoft Kinect became popular choice for work in sign language recognition when Kinect was launched in year 2010. Kinect traces motion in full body and has depth sensors that makes pose estimation of signer perfect. The author in [31] used Microsoft Kinect to recognize static as well as dynamic ISL signs using Multi-class Support Vector Machine (SVM). The features were extracted from 20 skeleton joints of a human body. The authors have achieved 86.16% accuracy on the test data. The author in [32] have proposed an approach to recognized single and double handed ISL signs using combination of Kinect and leap motion. Authors achieved 95.60% accuracy using Hidden Markov Model and Bi-directional Long-Short Term Memory (BLSTM) on 7500 gestures of ISL signs. Authors then used Coupled Hidden Markov Model (CHMM) with the concept of multi-fusion and achieved 90.80% accuracy in [33] for single handed signs. 83.77% accuracy was achieved by [34] for 2700 gestures with Kinect and leap motion. The authors used Coupled HMM to recognize single handed dynamic signs. Table I shows comparative analysis of vision-based Indian Sign Language gesture recognition systems considering camera as acquisition instrument.

The author in [8] proposed an approach to recognize ISL alphabets using double handed signs. Authors have created a dataset for 3 dynamic signs and created 60 videos. Authors have used YCbCr color segmentation and used Principle Curvature Based Region (PCBR) detector and Wavelet Packet Decomposition (WPD-2) methods with Dynamic Time Warping (DTW) classifier. Authors achieved 86.3% accuracy using Support Vector Machine (SVM).

TABLE I. REVIEW OF VISION-BASED DYNAMIC INDIAN SIGN LANGUAGE (ISL) RECOGNITION SYSTEMS

Year and Authors	Segmentation Technique	Feature Extraction Technique	Classification Technique	No. of Samples	Sign Types
Jayaprakash and Majumder, 2011	YCbCr	Principle Curvature Based Region + Wavelet Packet Decomposition-2 + convexity detect	Dynamic Time Warping	60	Alphabets
(Sahoo et al., 2019)	Skin color segmentation	Direct Pixel Value (DPV), local histogram, and hierarchical centroid (HC)	Artificial Neural Network	5000 (digits), 2340 (alphabets), 1250 (words)	Digits, alphabets and words
(Tripathi and Nandi, 2015)	HSV	Orientation histogram + Principle Component Analysis	Distance based classifier	60	Sentences
(Baranwal et al., 2017)	HSV, Otsu thresholding	Wavelet descriptor and Mel Sec Frequency Cepstral Coefficients (MFCC)	kNN, Support Vector Machine (SVM)	8	Words
(Kishore et al., 2016)	Horn Schunck Optical Flow	Active Contour model	Artificial Neural Network	1	Sentence having 58 words
Kishore and Anil (2016)	Sobel with adaptive block thresholding	Contour based model	Artificial Neural Network	18	Words
(Baranwal et al, 2017)	Background modelling	Wavelet descriptor	Possibility theory	20	Sentences
(Wazalwar and Shrawankar, 2017)	HSV	Pseudo 2-dimensional Hidden Markov Model	Harr classifier	60	Sentences
(Mariappan and Gomathi, 2019)	Skin segmentation feature of OpenCV	Regions of Interest	Fuzzy c-means clustering	130	Words, sentences
(Bhavsar et al., 2020)	Viola-Jones algorithm	Distance count and Correlation-Coefficient methods	Neuro-Fuzzy classifier	100	Words

The author in [35] created 1250 video for word signs, where each category has 125 videos. They have shown comparison of proposed approach with kNN and Artificial Neural Network (ANN) as classifier. For each video 2-5 frames are considered in sequence to identify words. The overall accuracy achieved using kNN classifier with DPV technique is 96.70% and with HC technique is 93.70%. This approach works for specific signer as ANN is trained on hand and face features. The author in [13] proposed continuous Indian sign language sentence recognition using various distance-based classifiers from which Euclidian and Correlation distance classifiers give accuracy up to 93%. Authors converted RGB frames in HSV frames using thresholding, from which hand portion was extracted. Meaningful sequence of frames was extracted by using gradient method. Hand features were extracted by using orientation histogram and then distance based classifiers were applied for classification. Segmentation of hand from upper half of the body and boundary changes depending on hand shape of various signers are solved by [11]. Authors have used OTSU thresholding method for segmentation, Mel Sec Frequency Cepstral Coefficients (MFCC) method for extracting features. But the algorithm doesn’t work on all geometric and photometric transformation techniques. Backpropagation algorithm was used by [36] on continuous sign language sentences using active contour hand shape features. Though the authors achieved 90.172% by capturing videos from four different signers, linguistic rules are not considered while performing sign language gestures.

The concept of possibility theory was used by [10] on 20 different continuous gesture videos of single-handed signs. These videos are captured with various backgrounds and multiple objects were used with black cloths having full sleeves. Authors achieved 92% accuracy on their own dataset.

The author in [12] proposed an algorithm for converting ISL sentences to English text. Authors used Pseudo 2-dimensional Hidden Markov Model (P2DHMM) for feature extraction, which is proven better than simple Hidden Markov Model. For converting recognized signs in English text, LALR parser was used. Major limitation of this work is that signs for words are recorded and then they are combined to create sentences. Furthermore, the algorithm worked for signs performed by single hand only.

The author in [37] achieved 90% accuracy on continuous signs captured using front camera of mobile phone. 10 signers have performed the sign of words and these words are arranged in specific order to create sentences. At the time of testing, video with same words with different order are given as input. The author in [38] discussed approach based on Fuzzy c-means clustering for recognizing sign words using 800 samples from different 10 signers. The author in [39] proposed an approach to classify word signs using Neuro-Fuzzy approach. Authors displayed the final word using Natural Language Processing (NLP) technique and achieved 95% accuracy.

To sum up, sign language recognition is a challenging problem as the recognition task involves visual and lingual information interpretation. Most of the research that has been conducted in Indian sign language recognition till date has considered this task as a gesture recognition problem, and ignores the linguistic properties of the sign language and has assumed that there is word-to-word mapping of sign to speech. Less amount of work is reported considering dynamic gestures of ISL words and these approaches works on limited vocabulary of signs. Also, all the work described here has considered manual components of signs, ignoring facial expressions. Moreover, most of the video capturing is done in controlled laboratory settings. No video sentence dataset is publicly available that is developed using ISL signs released by ISLRTC. Looking into these limitations, we were motivated to work in the direction of creating new dataset and an algorithm that works in fully functional way on this dataset without hampering video recognition accuracy.

III. INSIGNVID: Indian Sign Language Video Dataset

Currently no video dataset is publicly available for ISL sentence recognition using dictionary launched by ISLRTC, as discussed in Section 1. This section introduces dataset - INSIGNVID, containing set of video sequences of ISL sentences using word signs released by ISLRTC. Through recording it was observed that same signer can perform sign in slightly different manner each time; there may be variations in speed, gesture position and facial expressions. To incorporate these variations, signers have performed signs multiple times for each ISL sentence.

A. *Video Characteristics*

To create INSIGNVID, videos are captured from frontal view, using CANON EOS 700D digital SLR camera with 18 MP resolution. Videos are captured at 30 FPS (Frames Per Second), with a resolution of 1920 x 1088 pixels per frame. High resolution was used for recording videos because the facial expressions and hand movements would be captured in more detail in high resolution. This will facilitate researchers to convert the videos in low resolution, if required for specific applications.

Green background is used while recording the video because background removal is quite extensive task and it also affects the object recognition quality in real scenarios, if typical image processing techniques are used. If one wants to replace the background, a commonly used technique called as color keying can be used. Color keying can be done with any color having the background that is not matched with human skin color. Moreover, color chosen for color keying should be discrete and uniform. Green is commonly used color for color keying and it is generally preferred color over other colors as it requires less energy to produce uniform illumination over the color screen [40]. Due to this reason, all videos are captured using green backdrop. During the dataset creation, the distance between the camera and the signer is adjusted so that the dynamic gestures can be captured from upper part of the body. Later, using augmentation techniques, zooming and rotation can be performed to make generalized videos. While recording the videos of ISL sentences, proper lighting conditions are considered.

B. *Dataset Description*

55 most frequently used sentences were identified, after having discussion with teachers at Muk Badhir Seva Trust, Surat, India. All these sentences are composed of more than one word or hand strokes and are combination of single and double handed hand gestures. A total of 1289 videos of ISL sentences corresponding to 55 unique class labels have been captured with the help of signers. While creating dataset, signs were performed by a total of 4 right-handed signers. Green backdrop was used and black clothes were worn by signers while performing video. Signers of different age groups and both the genders have performed signs to make the system useful to all. To capture multiples variances in signs by each signer, the signs were captured 4-6 times from each signer. For capturing ISL videos of Deaf and authentication of signs performed, we have taken help and consent of ISL interpreter Ms. Mital Joshi, who is one of the certified ISL interpreters by ISLRTC. Table II shows some examples of English sentences and corresponding ISL sentences used for recording video sequences.

ISL is considered to be Subject-Object-Verb (SOV) language unlike English language which considers Subject-Verb-Object (SVO) order.

Sign languages do not use articles, linking verbs, prepositions of time like *for*, *by*, *during* etc. Fig. 1 shows sample frames of English sentence *Please wait for some time*. It can be observed from the frames that words please and wait are represented by single sign, while two signs are required to represent word time.

As shown in Fig. 2, sentence Look at the beautiful butterflies is represented as ISL sentence Beautiful butterflies look. Fig. 3 shows five sample frames of ISL sentence He look like his father for corresponding English sentence He looks like his father.

TABLE II. EXAMPLES OF ISL SENTENCES AND CORRESPONDING ENGLISH SENTENCES FROM DATASET-INSIGNVID

Sign Language Sequence	**English Sentences**
Her smile beautiful	Her smile is beautiful.
My daughter always happy	My daughter is always happy.
We late	We are late.
My brother restaurant work	My brother works in the restaurant.
Hello you how	Hello, how are you?
Wrong what	What's wrong?
You who	Who are you?
Tomorrow people come how	How many people will come tomorrow?
Thermometer where	Where's the thermometer?
I understand not	I don't understand
Problem no	No problem.
He banana eat no	He doesn't eat banana.
Good morning	Good morning
Thank you	Thank you
Hurry up we late	Hurry up, we are late!

Fig. 1. Sample ISL Frames for English Sentence Please Wait for Some Time.

Fig. 2. Sample ISL Frames for English Sentence Look at the Beautiful Butterflies.

Fig. 3. Sample ISL Frames for English Sentence he Looks Like his Father.

Fig. 4. Sample ISL Frames for English Sentence I Don’t Understand.

Fig. 5. Sample ISL Frames for English Sentence What is Your Name?.

In case of negation clause, word representing negation is signed at the end of sentence. Fig. 4 shows signs for ISL sentence I understand no corresponding to English sentence I don’t understand.

If the sentence is interrogative sentence, word representing question comes at the end of ISL sentence. For example, English sentence What is your name? is converted as Your name what in ISL, as shown in Fig. 5.

To sum up, the first ISL video dataset-INSIGNVID has been created, using ISL dictionary launched by ISLRTC. We hope that our video dataset will become a helpful resource to motivate research in field of gesture recognition, sign language recognition and human-computer interaction.

IV. Our Approach

The process of formation of English sentences from continuous ISL gestures mainly involves ISL video recognition. The design of the proposed approach is shown in Fig. 6 and the steps are discussed in detail below.

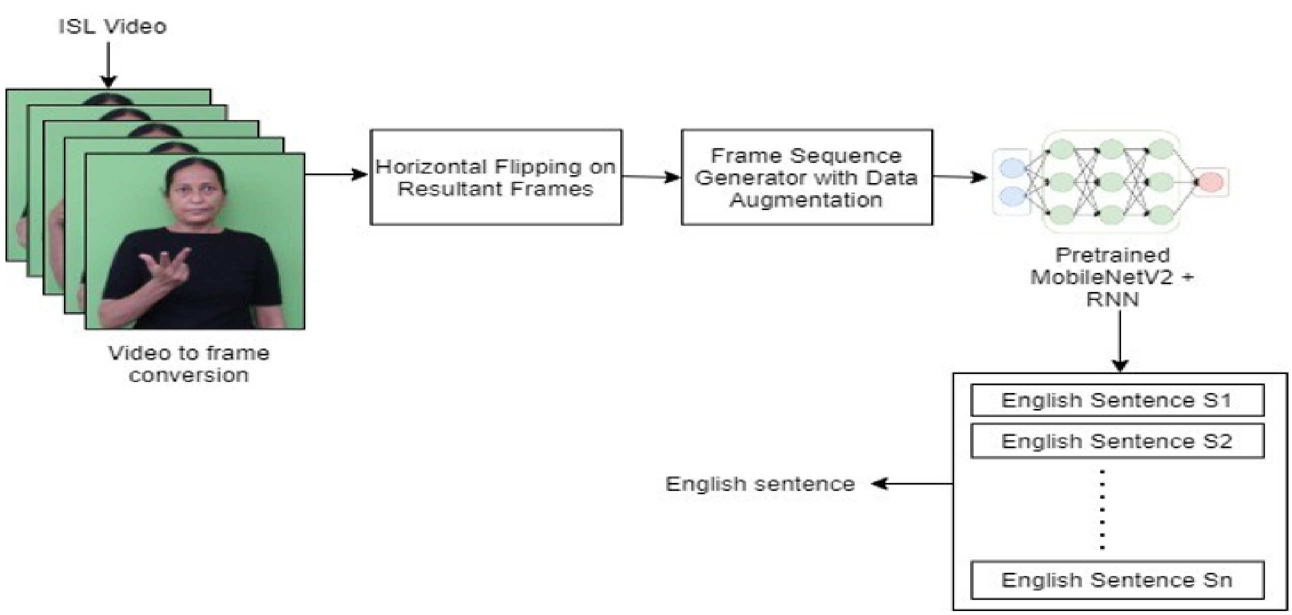


Fig. 6. Framework of Proposed Approach.

1) Video to frame conversion: Videos in dataset were captured using 30 fps, with resolution of 1920 x 1088 pixels. Taking these characteristics, RGB frames are generated for each video of different length.

2) Horizontal flipping: Signer can be either right-handed or left-handed. On the batch of frames, horizontal flipping is performed in order to incorporate both left-handed and right-handed signs. Though horizontal flipping is one of the data augmentation techniques, this technique has been explicitly separated from the other set. Reason behind this is, if online data augmentation technique is used, the modifications in images will be applied randomly, so not every image will be changed every time.

3) Frame sequence generator with image augmentation: To identify main frames, one possibility is that N distributed frames can be picked from the entire video. But this works only with fixed length of video as we may lose important information from frames. To address this issue, video generator is created that provides decomposed frames for the entire video in sequential form to get more sequences from one video file. For each 30 FPS video this video generator is used to select 5 frames per second. It has been decided to select every 6th frame based on analysis of histogram difference in frames. For each individual video, frames are selected in batches in order to get a set of shifted frames, such as first batch has frames 1, 7, 13, 19, 25 in sequence; second batch has frames 2, 8, 14, 20, 26 in sequence and so on. This custom generator supports image augmentation techniques. On the resultant images after frame sequence generator, geometric transformations - zooming, rotation, vertical shifting, horizontal shifting; and photometric transformations, augmentation on brightness are performed.

The author in [41] has discussed how to produce promising ways to increase the accuracy of classification tasks using data augmentation. It has been decided to work with augmentation techniques based on two aspects: Various video recording conditions and hardware dependency. For end-to-end ISL recognition, the environment in which signers perform signs under lighting and camera settings may be different. Signers may use different hardware devices such as camera, smartphone, tablets, computer with different resolutions and view. These variances are addressed by training the deep learning model with randomly selected augmentation types within range of parameters. It has been shown that training the recognizer with inflated data with randomness in augmentation gives remarkable improvement in accuracy. Image augmentation types and parameters were randomly selected with frame sequence generator.

4) Training with MobileNetV2 + RNN: Video frame generator is created that acts as video generator. We have taken 5 frames per second for each video. The inflated dataset after image augmentation technique is given as input to the Convolutional Neural Network (CNN). CNN architecture is selected for our work as it is best suited for capturing internal representation of features of visual world [42]. Here, our CNN is initiated with MobileNetV2 [43] model that was pretrained on ImageNet dataset. Pretrained model is chosen because image augmentation increases the size of the dataset which is originally very small but the data similarity is still very high. Also, MobileNetV2 is light-weight model that uses deep neural network that has proven best for mobile and embedded vision applications [43]. Fine-tuning is performed on the MobileNetV2 model by experimentally changing the top layer configuration of the model to get the best classification result. Moreover, LSTM (Long-Short Term Memory) model has been added that needs one dimension. As MobileNetV2 model is used without top layers, one Time Distributed layer has been added as a top layer to have the one-dimension shape compatible with LSTM. Finally, dense layer is added to get the prediction of English sentence. Output of overall process will be semantically equivalent English sentence corresponding to ISL sentence.

V. Experiments on INSIGNVID: Indian Sign Video Dataset

A set of experiments is conducted on our dataset - INSIGNVID, using our proposed approach. As discussed in Section 3.2, a total of 1289 videos have been used for training, validation and testing our model. Total videos are divided in three parts: 70% videos are used for training, 15% videos for validation and 15% videos for testing. The data used for testing has signs of the fourth signer which were not used for training and validation of the model. Therefore, the total number of training, validation and testing samples after horizontal flipping were 1808, 384 and 386, respectively. Frame sequence generator generates 5 video frames per second on which image augmentation techniques are performed. As a result, a total of 52432, 16848 and 16796 sequences are generated for training, validation and testing, respectively. Table III shows the statistics of image sequences after using frame sequence generator with data augmentation techniques.

The performance of MobileNetV2 model is also compared with three popular pretrained models used for object recognition: ResNet50, VGG16 and MobileNet. Table IV shows the comparison of model performance of MobileNet, MobileNetV2, ResNet50 and VGG16 models on.

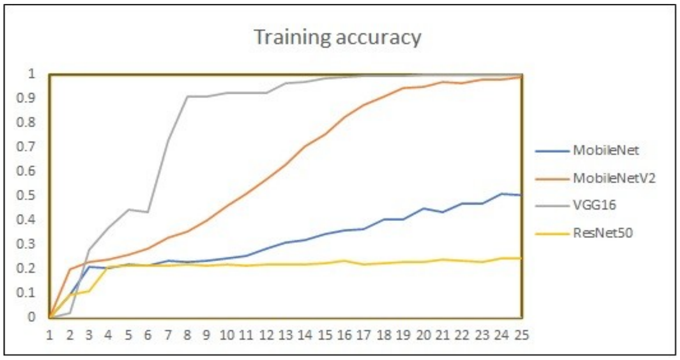
INSIGNVID after 25 epochs: Plots of accuracy and loss of all pretrained models are shown in Fig. 7. Here, it is important to note that even after 40 epochs (nearly after 35 hours), ResNet50 could not achieve accuracy more than 57%. VGG16 model achieves highest training accuracy but could get 89% testing accuracy. MobileNet model achieved 91% accuracy after 21 hours because it is slower than MobileNetV2 model.

TABLE III. IMAGE SEQUENCES AFTER USING FRAME SEQUENCE GENERATOR WITH DATA AUGMENTATION ON INSIGNVID

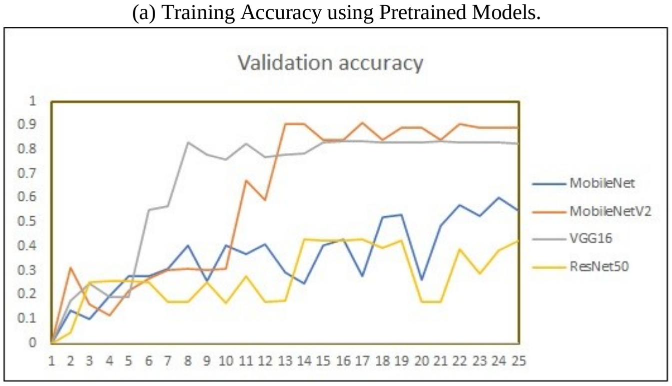
Parameters	**Values**
No. of classes (ISL words)	55
Average video length (seconds)	5
Total samples	1289
Training samples	904
Validation samples	192
Testing samples	193
Training samples after horizontal flipping	1808
Validation samples after horizontal flipping	384
Testing samples after horizontal flipping	386
No. of training sequences after using frame sequence generator	52432
No. of validation sequences after using frame sequence generator	16848
No. of testing sequences after using frame sequence generator	16796

TABLE IV. COMPARISON OF PRETRAINED MODELS' PERFORMANCE ON INSIGNVID

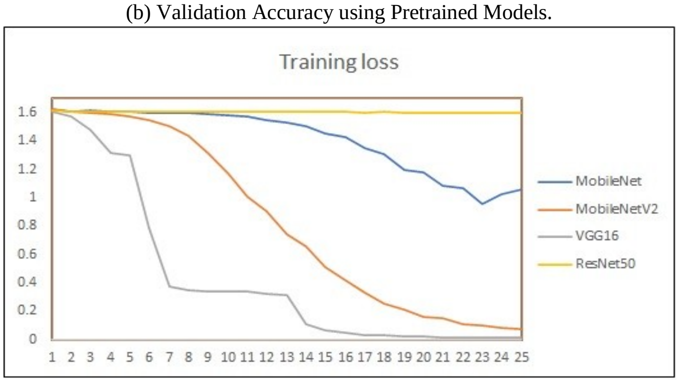
Parameters	**MobileNet**	**ResNet50**	**VGG16**	**MobileNetV2**
Model size (MB)	16	98	528	14
Trainable layers	9	9	9	9
Total Parameters	4,173,253	24,794,245	14,714,688	3,267,909
Non-trainable parameters	2,166,976	22,531,968	5,275,456	1,537,984
Trainable parameters	2,006,277	2,262,277	9,439,232	1,729,925
Time in hours (training + validation)	19.76	23.04	17.79	14.6
Training accuracy (%)	50.1	23.06	99.92	99.04
Validation Accuracy (%)	52.35	41.97	80.06	90.31
Testing accuracy (%)	50.4	32.09	89.06	93.89
Training loss	1.1068	1.60	0.0547	0.1981
Validation loss	1.1869	1.5875	0.953	0.2092
Testing loss	1.087	1.2624	0.1521	0.1735
Time in hours to get >=80% accuracy	23	Max. 57% after 35 hours	12.7	12.1



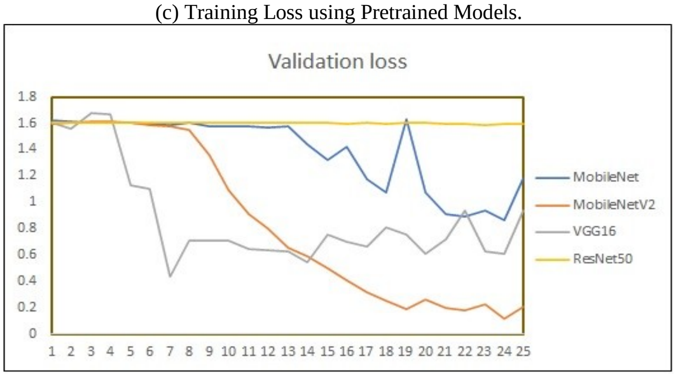
(a) Training Accuracy using Pretrained Models.



(b) Validation Accuracy using Pretrained Models.



(c) Training Loss using Pretrained Models.



(d) Validation Loss using Pretrained Models.

Fig. 7. Plots of Accuracy and Loss using Pretrained Models on INSIGNVID.

By looking at the comparison, it is clear that MobileNetV2 outperforms all other models for our dataset. 93.89% testing accuracy was achieved after 726 minutes, using MobileNetV2 model. Table V shows the hyperparameters used for all described models. Fig. 8 and Fig. 9 summarizes overall performance of proposed approach on our dataset - INSIGNVID. For calculation of precision, recall and F1-score, the following formulas are used [44]:

$$Precision = \frac{TruePositive}{TruePositive + FalsePositive} \quad (1)$$

$$Recall = \frac{TruePositive}{TruePositive + FalseNegative} \quad (2)$$

$$F - Score = 2 * \frac{Precision * Recall}{Precision + Recall} \quad (3)$$

TABLE V. HYPERPARAMETERS CONFIGURATION FOR PERFORMANCE COMPARISON BETWEEN PRETRAINED MODELS

Model configuration	**Parameters**
Model	Pretrained model + LSTM
Trainable layers	9
Learning rate	0.002
Dropout	0.4
Batch size	128
Activation function	ReLU
Optimization algorithm	Stochastic gradient descent

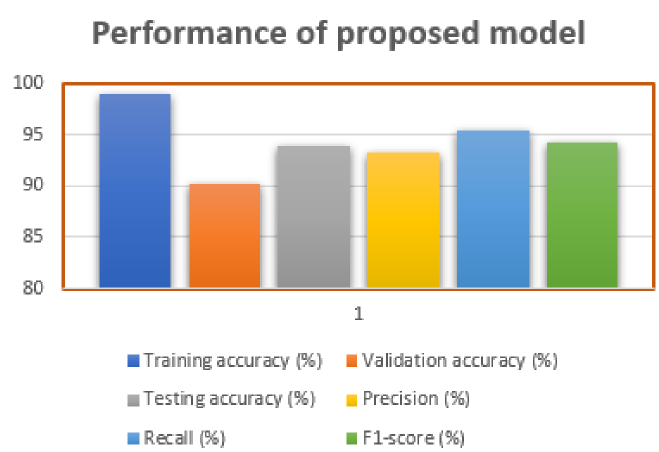
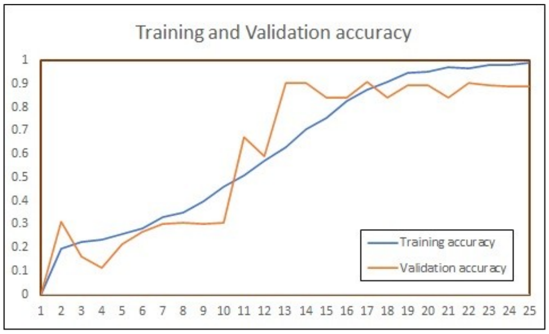
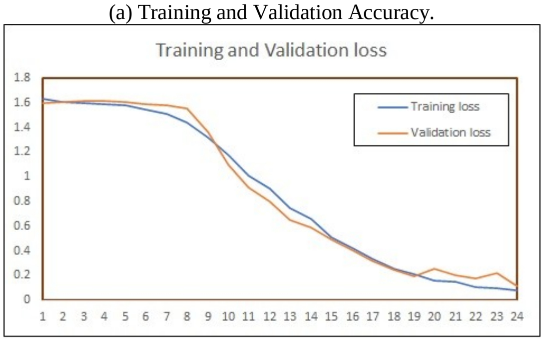


Fig. 8. Performance of Proposed Approach on INSIGNVID.



(a) Training and Validation Accuracy.



(b) Training and Validation Loss.

Fig. 9. Plots of Accuracy and Loss using MobileNetV2 on INSIGNVID.

VI. Conclusion and Future Work

Developing systems that translates sign language video in sentences is still a challenging task in India, as no video dataset for ISL sentences are available publicly. The existing datasets depend on local version of signs, have limited categories of gestures and have high variations in sign. At the same time, it is essential to work on continuous ISL sentence recognition, as it is primary language used by Deaf community to communicate with other people. Also, it becomes a challenging task when one wants to achieve more accuracy with a smaller number of samples in generalized environment. Deep learning gives promising results than other traditional algorithms in computer vision task as they learn features from gestures, but they require huge dataset. To overcome the problem of overfitting generated by deep learning models on less amount of data, image augmentation can be used before training data which also increases accuracy of test data. In this work, it has been empirically proven that simple image manipulation techniques and pretrained model with frame sequence generator creates great impact on the accuracy on ISL recognition than using very limited amount of data in training. An approach is proposed that uses pretrained model MobileNetV2 on our new dataset – INSIGNVID. This model learns features from augmented frame sequences of ISL gestures using batch of shifted frames to provide decayed sequences for the same gesture. Using MobileNetV2 as pretrained model on our dataset, promising results are shown for ISL sentence recognition.

In future, the proposed approach will be tested against unseen sentences. Furthermore, machine translation approach will be studied and implemented on parallel corpora of English and ISL sentences. The ISL corpus will be used for testing ISL sentences and the performance will be evaluated with evaluation parameters.

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Automated Pavement Distress Detection, Classification and Measurement: A Review

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Abstract—**Road surface distress is an unavoidable situation due to age, vehicles overloading, temperature changes, etc. In the beginning, pavement maintenance actions took only place after having too much pavement damage, which leads to costly corrective actions. Therefore, scheduled road surface inspections can extend service life while guaranteeing users security and comfort. Traditional manual and visual inspections don't meet the nowadays criteria, in addition to a relatively high time volume consumption. Smart City pavement management preventive approach requires accurate and scalable data to deduce significant indicators and plan efficient maintenance programs. However, the quality of data depends on sensors used and conditions during scanning. Many studies focused on different sensors, Machine Learning algorithms and Deep Neural Networks tried to find a sustainable solution. Besides all these studies, pavement distress measurement stills a challenge in Smarts Cities because distress detection is not enough to decide on maintenance actions required. Damages localization, dimensions and future development should be highly detected on real-time. This paper summarizes the state-of-the-art methods and technologies used in recent years in pavement distress detection, classification and measurement. The aim is to evaluate current methods and highlight their limitations, to lay out the blueprint for future researches. PMS (Pavement Management System) in Smarts Cities requires an automated pavement distress monitoring and maintenance with high accuracy for large road networks.**

Keywords—Automated pavement distress detection; smarts cities; pavement management system; machine learning; deep neural networks

I. INTRODUCTION

Damages detection and measurement in bridges, buildings and roads are not a recent focus of researches. Multiple studies [22] were conducted during the last decades to determine adaptable equipment and solutions. However, [23] keeping pavement surfaces in a good condition via a low-cost solution is still a big challenge.

There is no doubt that concepts of the future [24] (Smarts Cities, Smarts Roads, Smart Traffic, Intelligent Transportation Systems, etc.) are looking for automation, precision, energy-efficient and security while providing humans with the best services.

Nowadays, and besides the construction of multiple road networks, several cities are suffering congestion and overloading. For example [25], the number of private cars in China was 320 million in 2018; fifty-eight cities hold more than one million cars and seven cities support more than three millions.

Due to multiple causes, natural or human reactions, high qualities of roads surfaces are degraded and such situation cannot be avoided. When the severity of degradation becomes higher, it engenders multiple risks for road users and maintenance becomes costly and time-consuming. The run to failure concept is not the right solution and preventives actions can be conducted late or before it is necessary. The more accurate and efficient methods are those based on real-time monitoring [26], evaluating current status and estimating future development to decide on appropriate maintenance in every single timeslot.

Manual and visual inspection methods present an old concept. It takes more time, engages high manpower and presents multiple risks for inspectors and road users. For huge road networks, it is not practical at all to deploy inspectors along with the city to get a big amount of data, which is dynamic and space distributed.

PMS (Pavement Management System) is a concept that was adopted firstly in the State of California (USA) in 1979. The aim is to design a system taking all parameters that contribute to the pavement status into consideration and adapt, to the context, all methods and technologies to keep road surfaces in a good health.

Multiple types of sensors were used to collect data like vision, vibration, sound propagation, pressure, friction, etc. However, vision-based methods (images or videos) are more adaptable [21] because they overcome weather limitations and scan the whole area, which is not always possible for the remaining methods.

This paper is organized as follow. Section II describes PMS and its contribution to Smarts Cities development. Section III presents related works to pavement distress detection and measurement. In Section IV, experiences and results of current methods are depicted. In Section V, current limitations and futures research are highlighted. Before concluding the paper on Section VII, a discussion is presented in Section VI.

II. PAVEMENT MANAGEMENT SYSTEM

A. Concept

As long as cities become larges, an automated system to manage pavement condition becomes a reel need. In 1985, the American Association of State Highway and Transportation

Officials (AASHTO) was the first agency that defines the PM (Pavement Management), as: "The effective and efficient directing of the various activities involved in providing and sustaining pavements in a condition acceptable to the traveling public at the least life cycle cost". PM or PMS doesn't make decisions [28]; it just helps agencies to choose the best solution through the evaluation of alternative decisions.

B. Terms

The AASHTO [29] defined some terms relative to the Pavement Management as summarized in Table I.

TABLE I. PAVEMENT MANAGEMENT TERMS & DEFINITIONS BY AASHTO GUIDELINES

Term	**Definition**
Pavement Management (PM)	A program for improving the quality and performance of pavements and minimizing costs through good management practices.
Pavement Management System (PMS)	A set of defined procedures for collecting, analyzing, maintaining, and reporting pavement data, to assist the decision makers in finding optimum strategies for maintaining pavements in serviceable condition over a given period of time for the least cost.
Pavement Management Information System (PMIS)	An established and documented procedure for collecting, storing, processing, and retrieving the information required in a PMS. It represents a foundation for PMS since all pavement decisions must be based on a common, integrated source of information derived from reliable and good quality data.
Pavement Condition	The present status or performance of a pavement.
Pavement Maintenance Techniques Methods	Used to accomplish strategy or correct deficiency in pavement segment.
Pavement Management Strategy	A carefully arranged, systematic program of action applied to any area of pavement activity.
Pavement Performance	The assessment of how well the pavement serves the user over time. The engineer often associates pavement condition with an arbitrary, but quantifiable, value relating to pavement roughness, pavement distress, or pavement strength. Performance is the measured change of condition and/or serviceability over increments of time.
Pavement Optimization	A procedure for obtaining the greatest life-cycle benefits for the lowest cost. Within the practice of Pavement Management, optimization might best be described as a process of obtaining the highest state of pavement performance over the pavement's life cycle with the least social and economic impact.

C. Pavement Management System Implementation

To implement PMS in a special context, several models were proposed in the literature. Illinois Center for Transportation [27] proposed a model as follow:

- Step 1: Define the Roadway Network and Collect Inventory Data.
- Step 2: Collect Condition Data.
- Step 3: Predict Condition.
- Step 4: Select Treatments.
- Step 5: Report Results.
- Step 6: Select Pavement Management Tool.
- Step 7: Keep the Process Current.

D. Pavement Damages Classification

1) Pavement damages types: It should be determined to apply the appropriate maintenance. Distress shapes can be caused by factors mentioned in Section I. Pavement distress can be categorized as mentioned in Table II.

TABLE II. PAVEMENT DISTRESS CATEGORIZATION

Cracking	Fatigue Cracking (Alligator Cracking)
	Block Cracking
	Edge Cracking
	Longitudinal Cracking
	Transverse Cracking
	Reflection Cracking
	Slippage Cracking
Distortion	Rutting
	Shoving
	Depressions
	Upheaval
	Patch Failures
Disintegration	Raveling
	Potholes
Skidding Hazards	Polished Aggregate
	Bleeding
Surface Treatment Distress	Surface Treatment Distress
	Streaking

2) Pavement damages severity: Type of damage is not enough to define maintenance actions. Damage severity should also be measured.

Multiple documents defined models to categorize severity levels (low, medium, high, etc.). Categorization could be different from document to other.

R. Roberts studied and analyzed six documents of pavement distress classification methods [11]: American Society for Testing & Materials (ASTM) 2018, Miller & Bellinger 2014, British Columbia Ministry of Transportation & Infrastructure Construction Maintenance Branch 2016, Bertrand et al. 1998, Direzione Generale Infrastructure e-Mobilità Milano 2005 and VicRoads 2009. Analyzing the aforementioned documents reveals that distress evaluated as medium by a manual could be classified as lower or higher by other. Furthermore, some manuals defined the severity based on the distress dimensions and the ratio of the distressed area to the total surface square (ASTM, 2018). However, others use only the ratio parameter.

E. Pavement Surface Evaluation

The evaluation of pavement surface health is a combination of type and severity level of damages. Literature review analysis [17] indicates that the most indices used for pavement surface evaluation are:

- Pavement Condition Index (PCI);
- International Roughness Index (IRI);
- Ruth Depth (RD);
- Pavement Serviceability Index (PSI).

F. Pavement Maintenance

A.M. Johnson [7] has defined three types of pavement maintenance:

1) Preventive maintenance: Performed to improve or extend the functional life of a pavement. It is a strategy of surface treatments and operations intended to retard progressive failures and reduce the need for routine maintenance and service activities.

2) Corrective maintenance: Performed after a deficiency occurs in the pavement, such as loss of friction, moderate to severe rutting, or extensive cracking. It may also be referred to as “reactive” maintenance.

3) Emergency maintenance: Performed during an emergency situation, such as a blowout or severe pothole that needs repair immediately. This also describes temporary treatments designed to hold the surface together until more permanent repairs can be performed.

Predictive Maintenance is another concept adopted for pavement distress using Machine Learning, ANN (Artificial Neural Networks), or other algorithms to predict the future health of pavement. Despite the limitation of current algorithms, prediction models present a cost-effective concept that keeps surface roads healthy almost every time.

III. Related Work

A. Materiel and Equipment in use

1) Legacy methods: Visual and manual inspection methods of pavement surfaces were conducted by road inspectors using traditional tools. Almost data collected is suffering from subjectivity, not containing all parameters needed and presents a low quality. In this case, data collected is costly and time-consuming. Furthermore, infantile damages can’t be detected and still presents for a considerable amount of time until maintenance actions become heavy [1]. Otherwise, during a survey, the safety of inspectors and road users is highly engaged.

2) New technologies: Several sensors and equipment were used to evaluate pavement surface conditions by collecting different parameters [21]: image/video, acceleration, vibration, sound, pressure, friction, skid resistance, etc. During the last years, Condition Based Monitoring (CBM) was applied to pavement surface evaluation. Y. Hou summarizes intrusive sensors development and installation, as embedded equipment, in the pavement structure [26]. In this case, sensors are used to monitor the dynamic mechanical response of the pavement to vehicle load and weather influence. Data collected are transferred by the Internet of Things (IoT) technologies. Table III summarizes and categorizes sensors used.

TABLE III. SENSORS USED ON PAVEMENT DISTRESS DATA COLLECTION

Parameters collected	**Equipment used**	**Location of installation**
Image/ Video	Camera: CCD, CMOS, Infrared	Fixed around pavement.
	Smartphone	Mounted on vehicle; Moved by operator.
	Line Scan	
	UAV	Flying
Acceleration	Smartphone; Accelerometer	Mounted on vehicle : wheel axis, in-car
Vibration	Vibration sensor	Mounted on vehicle: wheel axis, in-car
3D Data	Laser Profiler; Line Projection; Stereovision; Kinect Device; Ground Penetrating Radar; Structured Light; Photometric Stereo	Mounted on vehicle; Moved by operator.
Sound	Microphone	Mounted on vehicle: on tire, beneath the car; Fixed around pavement.
Friction and Skid resistance	Tire (Traction); Wheel (Angled)	Mounted on vehicle
Pressure	Pressure sensor	Embedded in pavement structure
Temperature	Temperature sensor	
Humidity	Humidity sensor	
Stress	Stress sensor	
strain	Strain sensor	
Displacement	Displacement sensor	
Light	Light sensor	

B. Datasets

Data collected by sensors create datasets to train, evaluate and test algorithms. Multiple datasets are now available and open access. The quality of the dataset is determined by its volume, robustness, and exhaustiveness by containing data:

- Variable and complex;
- Collected under different weather conditions ;
- Collected with different lighting and noise levels;
- Blurry and degraded with high sample densest.

Datasets collected by acceleration and vibration sensors installed on cars do not handle all pavement surfaces. In this case, sensors collect only damages crossed by wheels' cars.

Datasets annotation adds information about distress types. Annotations can be done manually or by using algorithms (ex. Python). Some Datasets are annotated at the pixel level, which gives a clear idea about pavement condition and enhances the precision of algorithms.

We can make the dataset more exhaustive by applying the "Data Augmentation" method to the images collected. J. Liu [15] used image rotation (90◦, 180◦, 270◦) and flipping (180◦ horizontally and vertically) to get 7104 images from 1184 initially captured.

1) Vision datasets: Nowadays, it was proved that images/videos collection is more adaptable for pavement surface conditions [21]. Table IV summarizes datasets images of pavement. Besides the datasets mentioned, several researchers have collected specific datasets to test algorithms (ex. Crackdataset [2]). Those datasets were reserved for studies. Images extracted from videos give more information about damages. GAPs, GaMM and EdmCrack600 are a datasets containing video imaging.

TABLE IV. PAVEMENT CONDITION DATASETS

Dataset Name	**N° Of Images ↓**	**Resolution**	**Device**	**Privacy**
Street View Images	9 712	---	---	Private
NEU Inlaid Crack	9396	256 X 256	CCD camera & light	Private
Japan Road	9 053	600 X 600	LG Nexus 5X	Public
PID	7 237	640 X 640	Google API Street-View	Public
GPR Images	6 832	256 X 256	LTD-2000	Private
3D Asphalt Surface Images	2 000	4096 X 2048	PaveVision3D	Private
GAPs	1 969	1920 X 1080	Professional Camera	Public
FHWA/LTPP	1 056	3 072 X 2048	---	Public
Local	800	2 000 X 4 000	---	Private
EdmCrack600	600	1920 X 1080	GoPro 7	Public
Crack500	500	2000 X 1500	LG-H345	Public
Cracktree200	206	800 X 600	---	Public
CFD	118	480 X 320	iPhone 5	Public
CrackIT	84	1536 X 2048	Optical	Public
GaMM	42	1920 X 480	Professional camera	Public
Aigle-RN	38	991 X 462	Professional camera	Public

2) UAV datasets: Some studies [10, 20, 21] were used UAVs (Unmanned Aerial Vehicles) to inspect pavement condition. Aerospace imagery was applied in several domains (agricultural, mapping, forestry, surveillance, etc.) and proved valuable.

UAVs present the advantages of mobility along the third dimension, flexibility to change trajectory in flight, discretion, avoiding human risks and remote controlling. GSD (Ground Sampling Distance) is a parameter that defines the spatial resolution of images. Practically, it is the distance between adjacent pixel centers measured on the ground. Equation (1) shows the formula of GSD:

$$GSD = \frac{D \times Px}{f} \quad (1)$$

D: distance between UAV and ground

Px: pixel size

f: camera focal length

A low value of GSD means a high quality of image. The quality of UAV images increased with high camera resolution or low flight altitude.

C. Extraction and Analysis

Several algorithms (ANN, Deep Neural Networks and Machine Learning) were developed and tested to extract meaningful information from datasets. In this section, we will review articles published since January 2020 to evaluate the last researches in this domain.

1) Camera/smartphone images extraction: Q. Mei [1] presents a new Deep Learning algorithm for pavement cracks segmentation "DenseCrack". The algorithm was trained and tested on two datasets Crack Forest Dataset (CFD) and Imagenet.

W. Song [2] proposed CrackSeg, which is a Deep Convolutional Neural Network (CNN) for pavement cracks detection. CrackSeg was trained, evaluated and tested on CrackDataset which contains 8 188 images and was dedicated to the study. CrackSeg was also tested on CFD and AigleRN.

R. Roberts [3] makes the conception and the realization of a Low-Cost Data Acquisition and Analysis System for PMS in 3 phases:

- Phase 1: Pavement images collection by using two smartphones and one camera. The distance from the pavement surface was 1500 m.
- Phase 2: Conversion of images collected to 3D model by using SFM (Structure From Motion) technique.
- Phase 3: Analyzing images and Points Cloud by Cloud Compare.
- Phase 4: Points Cloud segmentation by using RANSAC and Fit algorithms.

Z. Tong [4] makes a combination of an FCN (Fully Convolutional Network) and a GCRF (Gaussian Conditional Random Field) to develop a new technique of pavement distress detection. This method enhances the precision of the detection by extracting more information about distress type, localization and dimensions. The algorithm contains a framework of incertitude calculation and a probability-based role to reject wrong segmentation. A dedicated dataset for algorithm training, validation and testing was collected by Datong SH5047XJCA2D5 (vehicle equipped with cameras). The dataset contains 8 820 images collected under different resolutions and formats by a vertical camera to the pavement surface.

Y. Du [5] used YOLO Network v3 to create a method of the detection and the classification of pavement damages. A dataset of pavement images was prepared using a camera installed on a vehicle. 45 788 images were captured along 200 KM of pavement under different weather and lighting conditions.

Z. Fan [6] suggested a group of CNNs based on Probability Fusion for automatic detection and measurement of pavement cracks. This method consists of three steps:

- Step 1: a group of CNNs was used to identify the structure of small cracks on raw images.
- Step 2: the average of all networks' outputs gives the probability of cracks on each pixel.
- Step 3: Skeleton algorithm measures the prediction of cracks' characteristics.

The proposed method was validated and tested on two datasets CFD and AigleRN. It can measure the width and the depth of different cracks (complex, thin, and intersecting cracks) based on a Crack Maps Prediction.

X. Xiang [9] proposed a new method for cracks detection based on an end-to-end trainable Deep CNN. The network was trained on Crack500 and evaluated on three datasets Crack500, Cracktree200 and CFD.

Q. Mei [12] proposed a cost-effective solution for pavement cracks inspection using a Grade Sport GoPro camera mounted on a vehicle. Two configurations of camera installation were studied (rear and front). Rear configuration was more advantageous for the following reasons:

- Light reflection from the windshield inside the car reduces image quality for front configuration.
- Front camera is relatively far from the pavement surface.
- FOV (Field Of View) of the front camera is reduced by the car's hood.
- Using backup cameras of cars in future researches to optimize equipment needed.

A new crack detection method ConnCrack was developed, which combines a Conditional Wasserstein Generative Adversarial Network and a Connectivity Maps. ConnCrack was pre-trained on two public datasets ImageNet and CFD. Then, it was trained and tested on the EdmCrack600 dataset collected for the study.

J. Liu [15] makes the conception of a method for pavement crack detection and segmentation based on a CNN in two steps:

- Step 1: automatic cracks detection using an algorithm based on YOLO V3 (modified).
- Step 2: cracks segmentation using an algorithm based on U-Net (modified).

Cracks detected during the first step will be segmented on the second step to enhance the method precision. A dataset of pavement crack images was collected for the study under different weather conditions and noise (stains, pavement markings, sealed pavement, sand, leaves, branches, shadow, etc.). 1 066 images were collected by a smartphone (dual cameras 13 Megapixels) at a fixed distance from the pavement (1.5 m). CFD dataset images (118) were added to the study dataset to get 1 184 images. Then, data augmentation was applied to get 7 104 images. Both methods (Step 1 & Step 2) were trained, evaluated and tested on the global dataset.

E. Ibragimov [18] proposes a method for automatic pavement distress detection based on Faster Region Convolutional Neural Network (Faster R-CNN). The study focused on four types of cracks: Longitudinal, Transverse, Alligator and Partial Patching. The validation of the method was conducted on a dedicated dataset collected for the study. Dataset (3 200 images) was collected by a high-resolution camera mounted on a vehicle moving at a speed of 30 km/h along 10 m * 3.7 m of pavement.

Y. Wang [19] creates a framework RENet "Rectangular convolution pyramid and edge enhancement Network" for pavement cracks detection. RENet is based on the modified ResNet-18 network, which is pre-trained on the ImageNet. The framework was tested on two datasets CRACK500 and NEU inlaid Crack and compared to 7 other methods (SMD, BC, MIL, Yin, NLDF, FCN, FPHB and SRM) on the same datasets.

2) Vision-based vs Vibration-based: J. Lekshmipathy [8] makes a conception and a comparison of two automatic methods of pavement distress detection, one based on vision and the other on vibration. All experiences for both methods were conducted on the same road segment (6.2km), and the results were validated by a manual survey. For the vibration method, accelerometers and gyroscope of a smartphone were used to collect data, and an Artificial Neural Network Technique was used to detect and classify pavement distress. For the vision method, data was collected by a camera (Sony Handycam, 8.9 Megapixels) mounted on the rear end of a car; images were captured at a speed between 10 and 15km/hr. Pavement distress detection and extension were conducted using a MATLAB code.

3) UAV images extraction: M. Zeybek [10, 20] used the mini UAV DJI Phantom 4 RTK (P4RTK) to inspect the condition of a road segment (100Meters) contains small cracks, potholes and ruts. The proposed method constructed on three phases:

- Phase 1: collection of images by a flying UAV.
- Phase 2: generation of Point Cloud (3D) and Orthomosaic with the SFM Pix4DMapper.
- Phase 3: damage measure (diameter, perimeter, width and depth) conducted on 2D and 3D data by Global Mapper Software.

R. Roberts [21] creates 3D models from UAV images by using SFM technique. The UAV used is the DJI Mavic 2 Pro (Commercial) with a 907g weight and 20Megapixels camera resolution. During data collection, 554 images were collected with a distance of 8 m from the ground and a GSD of 0.97mm/pixel. RANSAC (RANdom SAmple Consensus) and 2.5D Quadric Fit algorithms were used to segment images and evaluate the degradation levels.

4) GPR images extraction: J. Gao [13] makes the conception of Faster R-ConvNet (Region- Convolutional Neural Network), which is a Deep Learning method for pavement distress detection. Faster R-ConvNet was trained, validated and tested using 3785 GPR (Ground Penetrating Radar) images. Images were collected using LTD-2000 GPR (made in China) and containing different damages: Reflection Crack, Water-Damage-Pit and Uneven Settlement. During images collection, different frequencies were used to guarantee dataset integrality.

M. E. Torbaghan [14] proposed a method for automatic detection of cracks on road surfaces using GPR and established the limits of minimal dimensions detectable. The Singular Value Decomposition (SVD) algorithm reduces clutters on images. Then, a filter is applied to eliminate random noises. GPR images collection by Ground View 3 GPR (Utsi Electronics, 2GHz antenna) were conducted on seven pavement slabs samples. In total, 3.5m length of pavement contains 14 different cracks. Each slab is 500mm × 500mm × 110mm dimension. To test the ability of the system to detect pavement damages under environmental and physical conditions change, the following parameters were simulated:

- Cracks' surface was covered with paper to simulate the coverage of cracks by leaves' plants.
- Cracks were filled with thin layers of Bitumen to test the ability of the system to detect voids and cracks that do not penetrate to the surface.
- Cracks were filled with fine grains of sand to simulate debris and dust.

5) Transfer learning: S. Ranjbar [16] adopted the Transfer Learning technique to ML algorithms in order to solve the problem of a big data need for training. He trained, on a dataset, the Pre-Trained Models: AlexNet, GoogleNet, SqueezNet, ResNet-18, ResNet-50, ResNet-101, DenseNet-201 and Inception-v3. The dataset contains 1 500 images of pavement Linear Cracking, Surface Cracking and Non-Cracking.

IV. Experiences and Results

In order to make a significant comparison between algorithms, some indicators were defined and measured. The most indicators used are Precision, Recall and F1 Score.

A. Indicators Definitions

- Precision: the percentage of real cracks detected (TP) by a method from the total of real cracks existing (TP+FP) (2):

$$Pr = \frac{TP}{TP+FP} \tag{2}$$

- Recall: the percentage of reality (TP) on all cracks detection by a method (TP+FN) (3):

$$Re = \frac{TP}{TP+FN} \tag{3}$$

- F1 Score: is the harmonic average value of precision and recall (4):

$$F1\ Score = \frac{2}{1/Pr+1/Re} \tag{4}$$

During algorithm tests on a dataset, damages detection is compared to the real damages confirmed by dataset labels. However, it seems that some real damages are not detected by the algorithm, and some damages detection by the algorithm is not real. Damages accuracy verification can be done at the region or the pixel level. Finally, four situations can be defined:

S1: Picture/Pixel damaged according to the dataset and the algorithm; is counted as TP (True Positive).

S2: Picture/Pixel damaged according to the dataset but not detected by the algorithm; is counted as FP (False Positive).

S3: Picture/Pixel not damaged according to the dataset but supposed damaged by the algorithm; is counted as FN (False Negative).

S4: Picture/Pixel not damaged according to the dataset and the algorithm; is counted as TN (True Negative).

For Picture or Pixel level reasoning, the totals of counted TP, FP, FN and TN are calculated. Precision (Pr), Recall (Re) and F1 Score are calculated using (2), (3) and (4) respectively.

B. Cracks Detection

Several algorithms for cracks detection were proposed by the literature. To compare the performance of these algorithms, values of indicators (Precision, Recall, F1 Score) were collected and reviewed from publications. Table V summarizes indicators of the most popular cracks detection algorithms on the four datasets: CFD, CrackDataset, Aigle RN and EdmCrack600.

On the CFD dataset, the two steps concept based on the CNN proposed by J. Liu [15] get the best values of Pr (97.24%) and F1 score (95.75%). On the same dataset, the best value of Re (95.70%) were achieved by U-Net method based on Pixel-level crack detection [15].

On CrackDataset, CrackSeg achieved the best results on the three indicators: Pr=98.00%, Re=97.85% and F1 score=97.92%.

On Aigle-RN dataset, Z. Fan [6] achieves the best values of the three indicators: Pr=93.02%, Rec=91.66% and F1 score = 92.38%.

On EdmCrack600, best values were achieved by ConnCrack [12]: Pr=80.88%, Re=91.66% and F1 score=92.38%.

C. Non-Cracks Distress Detection and Analysis

Other methods were not limited to cracks studies, but they open the scope to analyze other damages: Pothole, Patching, Ruts, Manhole, etc.

R. Roberts [3] creates a low-cost imagery model for detecting and analyzing pavement distress. Images were collected using one camera (Nikon D5200) and two Smartphones (Huawei P20Pro and Samsung GalaxyS9). The accuracy of using mobile images to create 3D models was proved [3]. To evaluate smartphones' utility, Weibull parameters were measured (Shape and Scale) for the three distress surveys of the study, as illustrated in Table VI.

Y. Du [5] makes the conception of a method for pavement distress detection and classification based on YOLO Network v3. The method was tested on the dataset collected for the study, which contains three sets: 10 000, 20 000 and 30 000 images set. Best values were achieved on the 30 000 images set. For Manhole distress (9 567/30 000 images), AP=92.7% and F1=93.20% which represent the higher values. Minor values were relative to Potholes detection (1093/30 000 images) with AP=60.2% and F1=67.03%. On the same dataset, the algorithm was compared to Faster R-CNN and SSD using AP (Average Precision), F1 Score and operation time indicators (Table VII).

TABLE V. CRACKS DETECTION ALGORITHMS COMPARISON ON FOUR DATASETS

Algorithm	**CFD (%)**			**CrackDataset [2] (%)**			**Aigle RN (%)**			**EdmCrack600 [12] (%)**		
	Pr	**Re**	**F1**	**Pr**	**Re**	**F1**	**Pr**	**Re**	**F1**	**Pr**	**Re**	**F1**
Dense Crack 201	92.02	91.13	91.58									
Canny	43.77	73.07	45.70				19.89	67.53	28.81	1.69	34.17	3.14
FFA	78.56	68.43	73.15				76.88	68.12	68.17			
CrackTree	73.22	76.45	70.80									
CrackForest (SVM)	82.28	89.44	85.71	86.28	85.46	85.86	90.28	86.58	88.39			
MFCD	89.90	89.47	88.04									
CrackNet-V	92.58	86.03	89.18									
U-Net	92.54	89.51	89.90	96.99	97.09	97.04				76.33	70.88	71.52
Z. Fan (2020) [6]	95.52	95.21	95.33				**93.02**	**91.66**	**92.38**			
Local Thresholding	77.27	82.74	74.18				53.29	93.45	66.70			
Structured Prediction	92.27	94.89	93.12				91.88	88.61	90.21			
ResNet152-FCN	87.83	88.19	88.01							78.98	56.51	62.78
VGG19-FCN	92.80	85.49	88.53							80.22	59.93	65.18
ConnCrack [12]	96.79	87.75	91.96							**80.88**	**76.64**	**76.98**
Crack IT	67.23	76.69	71.64				76.85	74.32	76.56	12.33	7.14	4.75
J. Liu [15] (Two Steps)	**97.24**	94.31	**95.75**									
Ai. Jiang (2018)	90.70	84.60	87.00									
Jenkins et al. (2018)	92.64	82.82	87.38									
Bang et al. (2019)	93.57	84.90	89.03									
Nguyen et al. (2018)	93.06	89.31	91.14									
Fan et al. (2018)	91.19	94.81	92.44									
Cheng et al. (2018)	92.12	**95.70**	93.88									

TABLE VI. WEIBULL PARAMETERS IN THE THREE DISTRESSES SURVEYED [3]

DEVICE	**DISTRESS 1**		**DISTRESS 2**		**DISTRESS 3**	
	Shape	Scale	Shape	Scale	Shape	Scale
Huawei P20 Pro	1.186156	0.002275	0.941246	0.001772	0.725207	0.002148
Samsung Galaxy S9	0.981589	0.002794	1.005422	0.001528	1.183398	0.001785

TABLE VII. COMPARISON BETWEEN YOLOV3, FASTER R-CNN AND SSD ON THE COLLECTED DATASET [5]

Distress Type	**Higher AP**	**Higher F1 Score**	**Minor Operation Time**
Crack	Faster R-CNN : 49.3 %	Faster R-CNN : 54.88 %	YOLOv3 (Batch = 64) 364.965 /S
Patch-Crack	Faster R-CNN : 72.3%	Faster R-CNN : 76.58%	
Pothole	YOLOv3 (Batch = 64) : 38.6%	YOLOv3 (Batch = 96) : 40.88%	
Patch-Pothole	YOLOv3 (Batch = 64) : 63.3%	YOLOv3 (Batch = 64) : 68.55%	
Net	Faster R-CNN : 53.5%	Faster R-CNN : 56.90%	
Patch-Net	Faster R-CNN : 41.9%	Faster R-CNN : 44.32%	
Manhole	Faster R-CNN : 86.1%	Faster R-CNN : 90.45%	

Faster R-CNN makes good performances on detecting Cracks, Patch-Cracks, Nets, Patch-Nets and Manholes. However, YOLOv3 makes good performances on Pothole and Patch-Pothole detection and makes minor Operation time for all distress types detection (365 /S).

E. Ibragimov [18] develops an algorithm for automatic pavement damage detection based on Faster R-CNN. The method was tested on a dataset collected for the study that contains three types of damage: Linear cracks, area cracks and patching. The method makes good performances on detecting area cracks and patching. On patching detection, Precision, Recall, and F1 Score were respectively 84.00%, 88.09% and 87.21%. Difficulties were occurred on the detection of Linear Cracks (Longitudinal and Transverse): Pr=38.15%, Re=41.23% and F1=31.86%.

D. Algorithms Tested on UAV Images

M. Zeybek [10] used Pix4DMapper (SFM) to create Points Cloud 3D models based on UAV images. Global

Mapper software was used to detect and measure damages. Four features (diameter, perimeter, length and depth) were measured on four potholes and seven ruts. Software measurement was compared to data collected from a survey. Software errors (M soft – M field) and RMSE values are illustrated in Table VIII. M. Zeybek [10] proved also that measurement precision increases and error from field measurement decreases when the density of Points Cloud becomes large. As mentioned in Section III, the density of Points Cloud depends on the GSD value which depends on the UAV altitude. Four UAV GSD configurations were studied:

- 5mm GSD configuration presents the minor RMSE values: RMSE (diameter) = 4.41cm, RMSE (perimeter) = 0.03cm and RMSE (depth) = 0.03cm;
- 10mm GSD configuration: RMSE (diameter) = 8.53cm, RMSE (perimeter) = 4.18cm and RMSE (depth) = 0.03cm;
- 15mm GSD configuration: RMSE (diameter) = 16.29cm, RMSE (perimeter) = 6.08cm and RMSE (depth) = 0.03 cm;
- 20mm GSD configuration presents the higher RMSE values: RMSE (diameter) = 20.38cm, RMSE (perimeter) = 6.72cm and RMSE (depth) = 0.05cm.

TABLE VIII. ERRORS AND RMSE FOR DISTRESS MEASURED BY GLOBAL MAPPER SOFTWARE [10]

MEASUREMENT TYPE	SAMPLE	ERROR INTERVAL (cm)	RMSE
Diameter	4 Potholes	0.1 – 1.5	0.010
Depth	4 Potholes and 7 Ruts	0.1 – 3.7	0.009
Length	7 Ruts	2.0 – 15.5	0.301
Perimeter	4 Potholes	13.4 – 32.2	0.076

R. Roberts [21] used DJI Mavic 2 Pro (UAV) images to measure distress. During the 3D Cloud conception, the GSD was fixed on 0.97mm/Pixel to get 90 508 878 Points Cloud. RMSE values for Control Points and Check Points on the three3 axes (X, Y, Z) were measured. RMSE range was between 0.0078m and 0.0119m.

E. Algorithms Tested on GPR Images

J. Gao [13] proposed the Faster R-ConvNet method, which was trained and tested on a GPR images dataset contains four damages:

- Reflection crack: Pr = 88.31% and Rec = 89.04%;
- Water-damage pit: Pr = 90.56% and Rec = 89.68%;
- Uneven settlement: Pr = 88.51% and Rec = 91.04%;
- Overall: Pr = 87.13% and Recall = 89.92%.

M. E. Torbaghan [14] proposed a method for automatic crack detection based on GPR images. Table IX summarizes the ability of the method to detect cracks on raw and processed images. It was observed that on raw images, cracks width inferior to 8.6mm cannot be detected, between 8.6mm and 16.5mm were hard to detect and only superior to 31mm can be detected easily. However, on processed images, it was possible to detect cracks from 7mm width. On the other hand, PSNR (Peak-Signal-to-Noise Ratio) was analyzed for slabs uncovered and covered (with papers, thin layers of asphalt and filled with sand). PSNR for small-width cracks can't be analyzed.

F. Transfer Learning

To assure a good training for algorithms and reduce the need for a big amount of data, S. Ranjbar [16] trains a group of 8 pre-trained algorithms on a dataset containing 1 500 images. SqueezNet achieved the higher values of Accuracy, Pr and F1-score as illustrated in Table X.

TABLE IX. THE ABILITY OF THE METHOD TO DETECT GPR IMAGES [14]

Crack N°	LOCATION (cm)	WIDTH (mm)	RAW IMAGES	PROCESSED IMAGES
1	24.0	14.4	Hard	**Good**
2	59.0	1.1	No	No
3	88.5	4.5	No	Hard
4	110.0	16.5	Hard	**Good**
5	136.5	10.1	Hard	**Good**
6	161.0	8.6	No	Hard
7	192.0	1.3	No	No
8	210.0	31.3	**Good**	**Good**
9	239.0	3.4	No	**Good**
10	258.0	4.2	No	No
11	265.0	5.7	No	Hard
12	294.0	7.0	No	**Good**
13	317.0	34.2	**Good**	**Good**
14	371.0	4.7	No	Hard

TABLE X. COMPARISON OF PRE-TRAINED ALGORITHMS ON THE DATASET STUDY[16]

PRE-TRAINED ALGORITHMS	ACCURACY	PRECISION	F1 SCORE
AlexNet	97.80%	96.70%	96.70%
SqueezNet	**99.10%**	**98.60%**	**98.60%**
GoogleNet	98.90%	98.40%	98.40%
ResNet-18	97.90%	96.90%	96.80%
ResNet-50	97.40%	96.10%	96.10%
ResNet-101	97.20%	95.80%	95.70%
DenseNet-201	98.40%	97.60%	97.60%
Inception-v3	98.50%	97.70%	97.70%

Blood values are higher.

V. LIMITATIONS AND FUTURE RESEARCH

A. *Limitations*

Despite multiple researches conducted, automatic detection and maintenance of pavement distress are still reals issues in Smarts Cities. As we reviewed in previews sections, multiples sensors, software and algorithms were employed to find optimal solutions. However, results still under the perspectives of Smarts Cities' designers. Currents solutions are suffering multiple limitations on data collection, datasets construction, algorithms training and data analysis.

1) Data collection: sensors used to collect pavement data are facing the issue of getting details about small damages (~1cm). Environmental changes caused directly by small damages are very low. For this reason, parameters (such as temperature, vibration, etc.) are not very significant on pavement health monitoring concept.

GPR images are constructed based on electromagnetic signals reflected from pavement surfaces. Small damages reflect very weak signals that can't be easily analyzed, even if after processing operations.

Vision-based sensors (Cameras or Smartphones) are the best tools used for pavement monitoring. However, getting information about small damages depends on the camera's parameters (resolution, focal length and FOV). Despite using a high-quality camera, we should reduce the distance from the pavement, which is not always possible during traffic.

UAV makes great progress on pavement monitoring, by its ability to move around the pavement and collect images from different distances and angles. However, UAVs are still limited on embedded sensors types and quantity, weight, minimal altitude, range and the capacity of batteries.

2) Datasets: Multiple datasets present a limited number of images and distress types. Otherwise, a few datasets contain images with complex situations such as climate effects, low lighting and small objects noise. Also, the dataset should contain images with a high density of damages and degraded conditions.

3) Data analysis: most of the researches conducted were focusing on crack damages. Other types of damage (pothole, bump, ruts, etc.) are pending more specific methods and analysis. Otherwise, most of the papers are conducted on the field of the detection level. Measurement of pavement damages' dimensions (length, depth, diameter, perimeter, etc.) is still at its beginning. Also, studies and experiences were limited to small sections of the road. To the best of our knowledge, no study was conducted on monitoring a big network of roads as expected in Smarts Cities, to evaluate the ability of the system to handle a big amount of data.

B. *Futures Research*

To overcome the mentioned limitations and to achieve an efficient automatic pavement distress detection and measurement in Smarts Cities, we need to open the following scopes of research:

- Developing tools and methods for collection and analyzing small pavement damages ~ 1 cm.
- Generalization of pavement distress detection and measurement methods for other damages types than cracks.
- The conception of pavement damages datasets, exhaustive and dense, to avoid algorithms "Overfitting".
- Development of pavement distress detection and measurement algorithms based on "Ensemble Learning" and "Transfer Learning".
- Extraction of pavement damages from UAV videos streaming.
- Replace using multiple software and algorithms by End-To-End algorithms.
- Development of a GPS navigation system that can alert drivers about road damages.
- Using as a low-cost solution, Backup cameras and GPS navigation systems of cars to conduct pavement surface conditions.
- Development of a "User-Friendly" smartphone application to help drivers to avoid road damages.
- Using Google Earth images to enhance pavement distress datasets quality for a large roads network.

VI. DISCUSSION

Multiple software and algorithms were trying to extract meaningful information about pavement damage. Recently, Machine Learning and Deep Neural Networks are methods that achieved better results. The efficiency of these methods depends on the quality of data collected and algorithms training conduction. Multiple datasets were collected using fixed or mobile sensors to help with algorithms training, evaluation and testing. Several free datasets were collected under different conditions: weather, day/night, noise and data-making confusion (land markers, small objects, dust, etc.).

Until today, there are no robust methods or algorithms that can extract all existing distress, including small damages, on a big network of roads. Such a situation is sometimes due to the poor quality of data collected, the lack of training conducted for algorithms, or the non-possibility to handle a big amount of data at a determined timing.

Our concept will focus on using multiple UAVs (Unmanned Aerial Vehicules) to monitor roads surface. Videos will be taken from different altitudes and angles by multiple sensors. UAVs will be managed to capture all data required and transmit it to a ground station for validation or rejection. A pre-trained algorithm will be used to extract pavement damages from frames' videos. Fig. 1 illustrates the flowchart of our study.

VII. Conclusion

Automatic Pavement Distress Detection and Measurement is one of the most challenges in Smarts Cities. PMS (Pavement Management System) aims to keep road surfaces healthy and available all the time. For this reason, at each moment, pavement condition and futures evolution should be defined with high accuracy. We keep in mind that, Smarts Cities are looking for a low-cost solution, automatic, robust and able to handle a big amount of data.

During our review of state-of-the-art methods, it was observed that most of the papers were limited to the detection and measurement of specific damages on small pavement sections. Also, small damages were hard to analysis too and training still a real issues that needs to be overcome.

In Smarts Cities, roads networks are huge. For this reason, we need to deploy multiples sensors, to enhance the situation awareness about the health of road surfaces. The use of UAVs gives the flexibility to move around the three dimensions and change distances/angles from the pavement. Frames extracted from videos are containing meaningful information than simple images. To avoid overload, frames can be filtered before distress extraction operation.

Training of the algorithm is a critical operation that could be conducted periodically. Algorithm detection can be examined during surveys until detection achieves the accuracy and the maturity required.

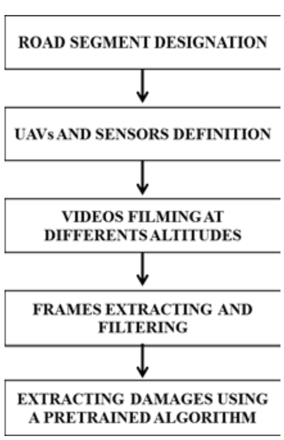

Fig. 1. Flowchart of the Study.

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A Model-driven Architecture for Collaborative Business Processes

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***Abstract*—The Model Driven Engineering was developed to make application development more flexible, it provides a comprehensive interoperability framework for defining interconnected systems, and aims to reduce the inherent complexity that partners must face when developing their systems. In collaborative environments where systems are made through the collaboration of several departments or companies, the MDA (Model Driven Architecture) approach seems efficient in maintaining and developing this type of system. This paper show the use of MDE in the context of business process management and present in detail an architecture for the development of collaborative business processes.**

Keywords—Model Driven Engineering (MDE); Business Process Model and Notation (BPMN); Business Process Execution Language (BPEL); ATLAS Transformation Language (ATL); BPMN to BPEL Transformation

I. INTRODUCTION

Business processes have become increasingly popular in the context of modernization and business reorganization. Business process management has been used primarily at the management level, to document ongoing activities and plan business improvements through reengineering projects [1]. Information Technology (IT) was primarily viewed as an enabling technology that provided adequate support for management tools. During the last years, business process management (BPM) is increasingly integrated into IT projects and workflow engines capable of directly executing business processes have emerged. Today's businesses need to quickly create and change value chains. This leads to continuous growth and change in business processes. The goal of Business Process Management (BPM) is to help people in the business to manage these changes. Business process management is defined as the ability to discover, design, deploy, execute, interact, operate, optimize and analyze the process in a comprehensive manner, doing it at the business design level and not at the technical implementation level. This development in business processes leads to benefits as well as problems in the management and implementation of processes and these problems persist even more when it comes to collaborative business processes. Collaboration requires analysis at the organizational level, changing internal business plans and ultimately finding the most suitable approach for implementation and management.

The modeling of collaborative business processes faces several challenges: The complexity of modeling intensifies during the coupling of business processes because each participant has their own set of "private" models which are modeled with different languages. Employees have heterogeneous application environments, different cultures and different business rules. The interoperability problem persists because every evolution or change in collaborative processes requires a lot of effort. In addition, general-purpose modeling languages, including UML (Unified Modeling Language), are difficult to understand for non-IT specialists, future users of information systems. Even if they read and accept the models, their understanding is not deep enough and they undervalue the consequences of the decisions behind these models. Information systems are not flexible and it is difficult to conform to models. If changes are made directly to the generated code, subsequent regeneration may undo them; faced with these problems in practice. Several research questions are asked but the three main ones are:

Q1: How to make collaborative business processes interoperable in a system.

Q2: How to define a DSML for modeling collaborative business processes.

Q3: How to implement these collaborative business processes.

To answer this question, this paper adopts a model-oriented approach based on Model Driven engineering (MDE). It was developed to make application development more flexible, it offers a comprehensive interoperability framework for defining interconnected systems. It aims to reduce the inherent complexity that partners must bear when developing collaborative processes, and to ensure that a conceptual solution (process level) is consistent with their respective systems (technological level). To support the design of collaborative processes, a specific language, called BPMN4Coll, has been proposed, which model collaborative business processes using very specific artefacts. The implementation of BPMN4Coll model is carried out with a model transformation using the ATL (ATLAS Transformation Language). The models produced are described by the BPEL (Business Process Execution Language). The latter allows the execution of models through process engine. This model separation allows a more flexible generation of applications and the development of user-friendly information systems.

The main advantages of this approach are:

- Increased level of abstraction, main development artifacts are collaborative process models independent of technology.
- Reduced development time and costs because solutions are generated automatically.
- Guarantee of consistency in the technological solutions generated because they are automatically generated from a well-defined transformation procedure: consistency with the processes defined at company level. In addition, the process specifications and interface specifications of the corresponding partners are also consistent.
- Independence of collaborative process models from Business to Business standards, which increases the flexibility of these models.

This paper is organized as follows: the second section explain the combination of MDE and BPM and how business process management can benefit from this approach. Section 3 is related work, it present some work that used the MDE in the modeling and implementation of business processes. Section 4 is devoted to explain this approach. Section 5 is an example to illustrate the transformation from BPMN4Coll to BPEL. Finally the paper is concluded in section 6.

II. Use of MDE in the BPM Context

Business Process Management starts with modeling processes. Process modeling is a business-driven exercise in which current and proposed process flows are documented in detail, linked to quantifiable performance metrics and optimized by simulation analysis. Standards for process modeling languages are key to achieving the goal of BPM as well as achieving platform independence of process models. Platform independence is one of the principles behind model-driven engineering (MDE). Thus, the combination of the two concepts, MDE and BPM, has become the target of several works. The MDE was designed to address several issues that have arisen over the past decade. On the one hand, the growing complexity of the platform, with thousands of classes and methods with very complicated dependencies. On the other hand, we can observe the continuous technological evolution of systems, forcing programmers to modify system code whenever a new requirement is given. In the MDE [13] paradigm, every concept must be modeled. Thus, any change in the system must be indicated in the template that represents that system. To model the systems, MDE suggests using domain-specific modeling languages (DSML). Thanks to these languages, different modeling notations are obtained for each type of system. Thereby, the software engineer has specific tools to model all types of systems. Another important concept in MDE is model transformation. By transforming models, the evolution of systems is facilitated. A model can be transformed into another model or into an XML specification as well as source code that implements the functionality of the model. The OMG Group developed the example of the Model Driven Architecture (MDA) of the MDE, which emerged, with the idea of separating the logic of the business specifications of a system from the specific platform details in which the system is implemented. The MDA adds some concepts to the MDE philosophy such as the definition of three levels of abstractions, which will be further detailed throughout this paper. By applying the concepts of MDE to BPM, this work try to reduce the gap between process description languages and formal execution languages. The idea is to have the technical team enhance the business processes transmitted by business analysts, by means of annotations and metadata. These improved business processes remain readable for trades people. Technical annotations are used to apply specific business and technical patterns to the project while hiding technical complexity and they are taken into account when generating executable workflows.

In fact, several studies show the great advantages of combining MDE and business processes. For example, in [2], the author proposes a tool that can be used in agile projects, thanks to the use of MDE, BPMN processes are systematically improved by means of metadata used to include specific transformation models business and technical oriented before generating executable BPEL processes. Thus, business analysts and technical team members can use a common modeling language like BPMN. This improves collaboration between the two teams and improves the overall efficiency and transparency of the project. From a business point of view, previously defined model fragments can easily be incorporated into new models. From a technical point of view, most of the complexity of the execution part can be hidden and the technical constructions are encapsulated in appropriate model transformations. A systematic review carried out by [3] provides a comprehensive view of the propositions and opinions existing in the literature on the application of the MDE paradigm in the management of business processes. Most of the work found indicates the use of model-driven engineering as a valid approach to business process management. There are proposals for using MDA in the context of collaborative business process management, where the driven model acts as an integration standard and allows different organizations to cooperate from a business process perspective. On the other hand, it suggested that MDA is the methodology that guides the design, implementation, maintenance and management of the operational processes of the organization. However, although there is some rejection of this idea, highlighting how far apart the two concepts of MDE and BPM are, and how difficult it is to get cooperation to achieve better results. Most authors are in favor of using MDE in business process management.

III. Related Work

In literature, for dealing with collaborative business processes, the MDE approach is identified as a key catalyst for building a model-based development method. The separation of the layers adopted by this approach has been the interest of several works. In [4], the author describes the process of developing his approach, which is based on two phases, the first being the technology independent phase, the author has created a modeling language (UP-ColBPIP) which is based on interaction protocols to describe the behavior of collaborative processes. The second being the specific platform phase, the author describes how he will implement these collaborative processes. The author's approach respects the separation of the business and technology layer of the MDA, however, the use of the language (UP-ColBPIP) which is an extension of the UML2 does not seem very interesting given that the latter is quite complex for people in the trade or non-IT specialists to understand. Other works like [5], proposes a Framework for the modeling of collaborative business processes, its methodology is based on the MDA approach. It offers a generic metamodel in order to instantiate it as a collaborative business process from which the respective internal business processes of the partners can be derived. Its Framework allows each partner to model with different languages and keep their own working tools. In [6], the author proposes a semi-automatic transformation from the CIM (Computation Independent Model) layer which uses BPMN to the PIM (Platform Independent Model) layer which uses UML, then from the PIM layer to the PSM (Platform Specific Model) layer which uses IFML (Interaction Flow Modeling Language) which is a standard for representing the web interface model. Transformations are performed using rules well defined by ATL. In [7] and [8], the author proposes a semi-automatic transformation from the CIM layer to the PIM layer structured by the (Model-View-Controller) MVC pattern. The CIM layer is represented by BPMN notation and UML activity diagram, as well as, PIM layer is represented by the state, class and package diagrams. The author in [9] proposes a semi-automatic transformation of secure processes to use cases. In CIM layer, the author models the secure process via a BPMN extension. Then, through a set of transformation, refinement rule and checklist, it transforms these process models into use case models at the PIM layer. In [10], at CIM layer the author models the processes with the BPMN standard and uses the value models to identify the services. Then, at the level of the PIM layer, the models are modeled thanks to an extension of the UML activity diagram and the UML use case diagram.

IV. Approach for Collaborative Processes

A. *Definition of the Approach*

In the business world, before collaborating or developing an information exchange interface, collaborators must be involved, mutually engaged, have mutual trust, shared risks, responsibilities and rewards. Indeed, the collaborators must agree on a final goal, and define common objectives, which represents a synthesis of the individual objectives. Identify the participants in the process, the roles that perform and their relationships. Define the management rules that explain the confidentiality chart and the type of data or shared tasks. This work try to respect the concepts of collaboration defined in the previous work [9]. This approach consists of three phases, see Fig. 1:

- Business Level (Phase1): In this level no IT considerations appear. It is a business layer that allows employees to analyze the problematic of the field. It consists in analyzing the requirements of the collaborators and identifying the business need. The Output of this phase is a set of requirements that helps business analysts to understand the problem and identify the collaborative business process that needs to be designed in the next phase.

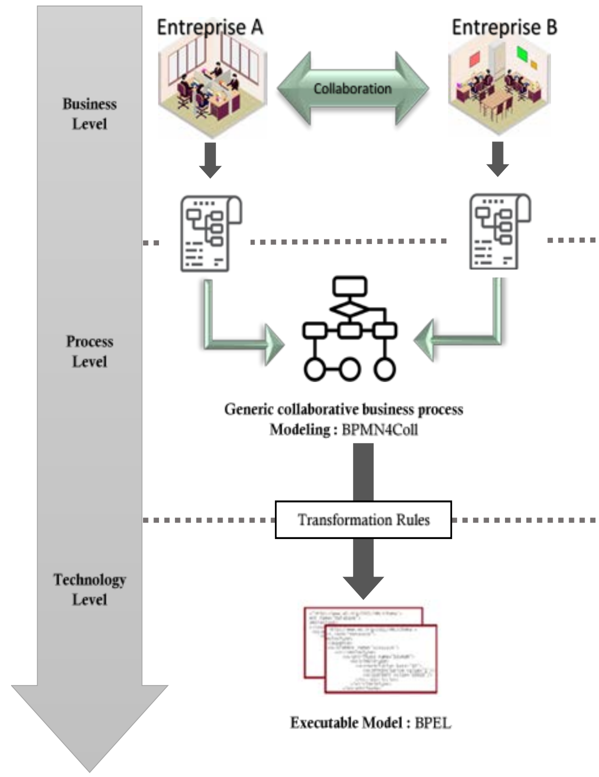

Fig. 1. Model-Driven Architecture for Collaborative Business Processes.

- Process Level (Phase2): This phase represents a layer for modeling the collaborative aspects of the participants. For that, we create a specific modeling language for collaborative environments. It is called BPMN4Coll (it will be further explained in section 4.2) is an extension of the BPMN language that allows a graphical, clear and understandable representation of collaborative business processes. The Output of this phase is a BPMN4Coll Model that describes collaborative process and will be transformed in the next phase in an executable Model.

- Technological Level (Phase3): It is a technical layer, which allows the generation of collaborative processes. The last step of the approach corresponds to the implementation of collaborative business processes. In practice, at this level, collaborative business process are modeled by BPMN4coll DSL. The advantage of this DSL is that it can be transformed into BPEL. We chose BPEL for the execution since the BPMN4Coll is an extension of the BPMN that can be executed thanks to the BPEL. In addition, BPEL is an executable language supported by several tools, it is used to specify interactions with web services and it defines business processes using XML-based language. The transformation is explained further more in section C.

B. *BPMN4Coll: Collaborative Business Process Modeling Language*

The level of modeling process represent a general view of the system independent of the platform. Describe the system without showing the details of using this platform. It can be adapted to different architectures. In this case to deal with the problematic related to collaborative business process, a platform-independent DSL (Domain Specific language) called BPMN4Coll is defined. The latter does not present any technical details and can be transformed into an executable model.

The BPMN4Coll language defined in the previous work [11] is a DSL that allows both technical people (engineers or technicians) and people in the trade to represent their business processes. In addition, the language is dedicated to the representation of collaborative processes that require consistent interaction between participants. The language can be used to model all types of systems. Fig. 2 illustrate an extract of BPMN4Coll metamodel used to perform the transformation in the next step.

The language is defined using the BPMN extension mechanism [12]. It extends two main elements of BPMN (Activity and DataObject) by associating new collaboration elements. This also means that the use of other basic elements of BPMN (such as flowObject, gateway, etc.) remains valid. BPMN4Coll presents an abstract syntax as a metamodel conforms to MOF and their instances models have ".bpmn4coll" extension.

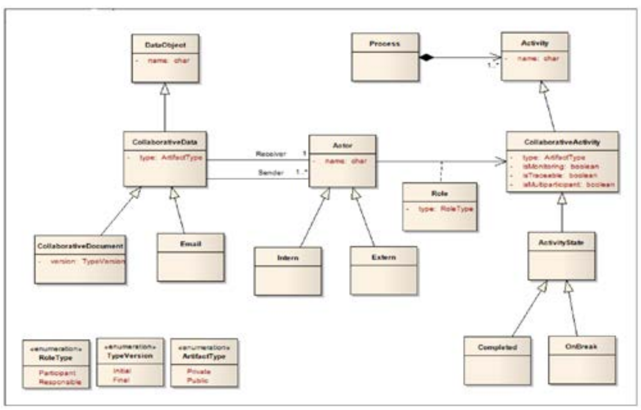

Fig. 2. An Extract of BPMN4Coll Metamodel.

C. Model Transformation from BPMN4Coll to BPEL

1) Transformation steps: In order to make development by model operational, flexible and more productive, the MDE has enriched them through the concept of model transformation. Transformation is an operation that allows the generation of one or more target models, from one or more source models in accordance with well-defined rules. The transformation is exogenous since the source and target model are conform to different metamodels. And it is unidirectional from BPMN4Collaboration to BPEL, see Fig. 3.

The transformation is based on a model-to-model Transformation. However, the underlying metamodel BPMN4Coll and the underlying metamodel BPEL are not identical; in fact, they are very different. Thus, the transformation is not straightforward and sometimes requires mappings between the two languages. The process of transformation shown in Fig. 3 present the steps of the transformation:

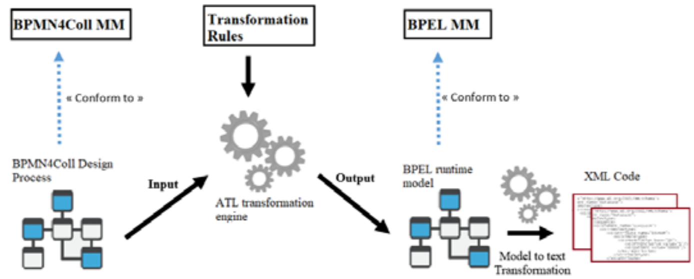

Fig. 3. ATL Transformation from BPMN4Coll to BPEL.

- The use of ATL language (Atlas Transformation Language) to perform this transformation.
- The BPMN4Coll metamodel: represent the source model of transformation (see Fig. 2).
- The BPEL metamodel: represent the target model of transformation (see Fig. 4).

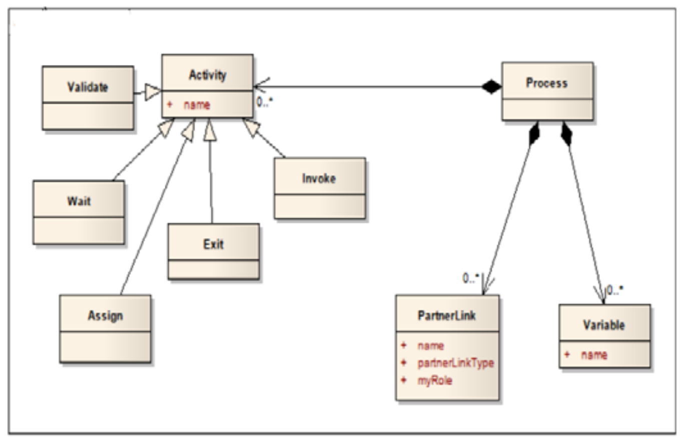

Fig. 4. An Extract of BPEL Metamodel.

- The rules transformation: represent the mappings between the two languages (see the next section).
- Identifying the correspondences between concepts of the source and target models at the level of their metamodels, Table I:

TABLE I. THE CORRESPONDENCES BETWEEN THE BPMN4COLL AND BPEL

BPMN4Coll Concepts	***BBEL Concepts***
Process	Process
Sequence flow	Sequence
Role	PartnerRole
Collaborative Activity	Invoke
Activity OnBreak	Wait
Activity Blocked	Exit
{Intern/Externe} Actor	PartnerLink
CollaborativeData	Variable

2) Transformation rules: This section present some ATL rules used to transform BPMN4Coll metamodel to BPEL metamodel:

- R1: CollaborativeActivity2 Invoke

– Invoke keeps the same name as Collaborative activity concatenated to the word "_coll" to define that is a collaborative Activity.

– Define the boolean type isMultiparticipant helper, which shows that the activity is performed by another participant. If isMultiparticipant returns "true" then all the actors of the activity must be transformed into partnerlink;

– If the type attribute of CollaborativeActivity is "Private" then all CollaborativePartner must have the type "intern"

– If the type attribute of the CollaborativeActivity is "Public" then invoke must have at least one "extern" type actor.

– If the isTraceable attribute of the CollaborativeActivity is "True" then Invoke must have as output a document that ranks the activity traces.

– If the isMonitoring attribute of the CollaborativeActivity is "True" then Invoke must be attached to an actor whose role is responsible.

- R2: Role2Partnerlink

– The attribute Type of the activity Role corresponds to the myRole attribute of the activity partnerlink.

- R3: Actor2PartnerLink

– The Actor activity of BPMN4Coll corresponds to the PartnerLink activity, by adding to partnerLink a new attribute "collaborativePartner" which takes two values {Intern | Extern}.

- R4 : Completed2Assign

– The Completed activity is transformed to assign activity with the "validate" option enabled.

- R6 : CollaborativeData2Variable

– The activity Variable keeps the same name as CollaborativeData concatenated to the word "coll_"

– If the type attribute of the CollaborativeData activity is of the value "Private" then all associated CollaborativePartner must be of type "intern"

– If the type attribute of the CollaborativeData activity has the value "Shared" then Variable must have at least one "intern" type actor and one "extern" type actor.

- R7 : CollaborativeDocument2Variable

– The CollaborativeDocument is transformed the Variable activity by adding the attribute version.

3) Implementation of transformation: To achieve the goal of transformation between BPMN4Coll and BPEL, we use the ATL plugin of the eclipse environment. Eclipse is a universal platform that offers an integrated development environment. Its goal is to provide a modular environment to easily carry out IT developments. The development of new functionalities is done thanks to the concept of modules called plugins. This concept allows providing a mechanism for the extension of the platform and thus offers the possibility to third parties to develop new functionalities, which are not provided by the tool. Eclipse includes a framework for manipulating MOF metametamodel compliant models, including EMF (Eclipse Modelling Framework). The latter is based on a metamodel called Ecore, which resembles the EMOF 2.0 metamod (subset of MOF 2.0) and helps describe models and provides support for their execution and manipulation in the form of Java objects. It stands as a benchmark in model-driven development.

To achieve the transformation we first present BPMN4Coll and BPEL meta-model into Ecore format. Then, define the transformation engine. On the on hand, ATL language is a hybrid transformation language that clearly separates the two declarative and imperative parts. On the other hand, the source domain is read-only and the target domain is write-only, which allows greater flexibility to the language.

```
module BPMN4Coll2BPEL4Coll;
create OUT: BPEL4Coll from IN: BPMN4Coll;

-----------------------------Helpers----------------------------------------
-- this helper checke if the artifact is private
helper context BPMN4Coll!CollaborativeActivity def: isPrivate(): Boolean =
if self.actor->select(a | a. oclIsKindOf (Intern)).size()=1 and
self.actors->select(a | a. oclIsKindOf (Extern)).size()=1then
true else false
endif;
-- this helper checke if the artifact is public
helper context BPMN4Coll!CollaborativeActivity def: isPublic(): Boolean =
if self.actor-> select(a | a. oclIsKindOf (Extern)).isEmpty()then
true else false
endif;
--  this helper checke if the activityis multi-participant
helper context BPMN4Coll!CollaborativeActivity def: isMultiparticipant(): Boolean =
if self.actor -> size()>= 1 then
true else false
endif;
-- this helper checke if the activity is traceable
helper context BPMN4Coll!CollaborativeActivity def: isTraceable(): Boolean =
    if self.actor->select(a | a. oclIsKindOf (Intern)).size()=1 and
    self.actors->select(a | a. oclIsKindOf (Extern)).size()=1 then
true else false
endif;
-- this helper checke if the activity is monitoring
helper context BPMN4Coll!CollaborativeActivity def: isMonitoring(): Boolean =
 if self.isMonitoring implies self.actor.role -> select
 (r | r.type == RoleType::Responsible) -> size() >= 1 then
true else false
endif;
-----------------------------Rules------------------------------------------
rule MultiparticipantActivity2Invoke{
     from s:BPMN4Coll!CollaborativeActivity(s.isMultiparticipant()= true )
     to e: BPEL4Coll!Invoke(
         name<- s.name )
     }
rule MonitoringActivity2Invoke{
     from s:BPMN4Coll!CollaborativeActivity(s.isMonitoring()= true)
     to e: BPEL4Coll!Invoke(
         name<- s.name )
        t: BPEL4Coll!PartnerLink(
         myrole <- 'Responsible' )
     }
rule Role2PartnerLink{
     from s:BPMN4Coll!Role
     to e:BPEL4Coll!PartnerLink(
         myRole <- s.type)
     }
rule Actor2PartnerLink{
     from s:BPMN4Coll!Actor
     to e:BPEL4Coll!PartnerLink(
         name <- s.name)
     }
```

Fig. 5. Code Source of Some Helpers and Rules.

The BPMN4Coll language is an extension of BPMN so it is obvious that it consist of the same BPMN elements. Thus, in this work it is not a question of transforming all the elements of the BPMN4Coll language to BPEL because in the literature there are several works dedicated to the problem of transforming BPMN to BPEL. The objective of this work is to accomplish the transformation of new collaboration concepts added by the BPMN4Coll extension. For this, we need to create helpers and rules, which define the new collaboration concepts and then define the declarative rules for producing the input elements. The Fig. 5 present some helpers and rules used in the ALT Transformation.

V. Illustrative Example

This section try to give examples of transforming a simple of a client/Provider process Fig. 6 which is modeled with BPMN4Coll language onto the corresponding BPEL schema; using rules define in the previous section.

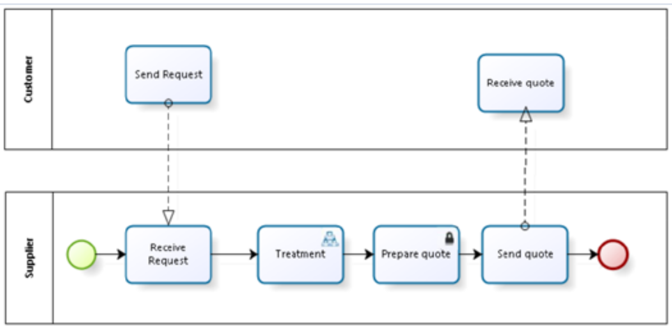

Fig. 6. Example of a Simple Process Modeled by BPMN4Coll.

The example represents a simple process that illustrates the request for quotation operation from a supplier. The process consists of two participants (the customer and the supplier), It begins with the receipt of a request for quotation. Then the supplier processes the request. Then he calculates and prepares the estimate. Finally, the process ends by sending the quote to the customer. The two activities "treatment" and "Prepare quote" are collaborative activities; the first one is of the multi-participant type as well as the second is a private or confidential activity.

The result of the ATL transformation of the previous example is the extract of the BPEL code presented in Fig. 7. The first part <process> defines the process information, in this case the process name is "supplier". Then we define the other processes (or services) with which it will interact in this case "EntrpriseA" and "Customer". Then, we define the variables accessible throughout the process.

The second part represents the main body of the process which consists of a set of activities. The <sequence> part represents a set of activities executed sequentially, it contains a <receive> reception activity to obtain the input message to start the process. <Invoke> represents collaborative activity and <Reply> element is used to send the final message for closing the process.

Finally we close the process with </process>.

```
<process name="Supplier">
.
.
.
<partnerLinks>
    <partnerLink name="EntrepriseA"/>
    <partnerLink name="Customer"/>
</partnerLinks>
<variables>
    <variable name="Request" messageType="tns:EntrepriseAReceiveMessage" />
    <variable name="RequestInfo" messageType="tns:TreatmntReceiveRequestInfo"/>
    <variable name="RequestTreatment" messageType="tns:TreatmentResponseRequestInfo"/>
    <variable name="Quote" />
</variables>
<sequence name="mainSequence">
    <receive name="receive Request" partnerLink="customer"
             operation="process" variable="Request"
             createInstance="yes"/>
    <invoke name="Treatment" operation="RequestInfoTreatmnt"
            inputVariable="Request"
            outputVariable="RequestTreatment">
        <PartnerLinks>
            <PartnerLink name="Supplier" myRole="Responsible"
                         collaborativePartner="Intern" />
            <PartnerLink name="EntrepriseA" myRole="Participant"
                         collaborativePartner="Extern"/>
            <PartnerLink name= "customer" myRole="Responsible"
                         collaborativePartner="Extern"/>
        <PartnerLinks/>
    <invoke/>
    <invoke name="prepare quote" operation="QuotePreparation"
            inputVariable="RequestTreatment"
            outputVariable="Quote">
        <PartnerLinks>
            <PartnerLink name="Actor1" collaborativePartner="Intern"
              myRole="Responsible"/>
        <PartnerLinks/>
    <invoke/>
    <reply  name="Send quote"  partnerLink="customer"
            variable="Quote" operation="process""/>
</sequence>
.
.
</process>
```

Fig. 7. The Example Transformed into BPEL.

VI. Conclusion

The modeling of collaborative business processes faces several challenges: The complexity of modeling intensifies during the coupling of business processes because each participant has their own set of "private" models that are modeled with different languages. Employees have heterogeneous application environments, different cultures and different business rules. The interoperability problem persists because an evolution or change in a collaborative process requires a lot of effort. To solve these problems we opted for an of MDA approach which allows to:

- Increased level of abstraction because collaborative process models are technology independent.
- Guarantee of consistency in the technological solutions generated because they are automatically generated from a well-defined transformation procedure.
- Independence of collaborative process models from Business to Business standards, which increases the flexibility of these models.

The main objective of this architecture is the separation of the two business and technological layers. Thus, achieve the design of collaborative processes independent of the particularities of B2B standards. In fact, to support the design of collaborative processes, this work propose a graphical DSL named BPMN4Coll based on BPMN and specific to the field of collaborative business processes. Then, the automatic generation of executable processes from conceptual models of collaborative processes. This second phase of the approach focuses on the implementation of these collaborative processes, thanks to a transformation of the BPMN4Coll models into an executable process written in BPEL.

The next work will provide more details on the ATL transformation engine as well as a use case to make our approach a reality.

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Comprehensive Study on Machine Learning Techniques for Software Bug Prediction

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***Abstract*—Software bugs are defects or faults in computer programs or systems that cause incorrect or unexpected operations. These negatively affect software quality, reliability, and maintenance cost; therefore many researchers have already built and developed several models for software bug prediction. Till now, a few works have been done which used machine learning techniques for software bug prediction. The aim of this paper is to present comprehensive study on machine learning techniques that were successfully used to predict software bug. Paper also presents a software bug prediction model based on supervised machine learning algorithms are Decision Tree (DT), Naïve Bayes (NB), Random Forest (RF) and Logistic Regression (LR) on four datasets. We compared the results of our proposed models with those of the other studies. The results of this study demonstrated that our proposed models performed better than other models that used the same data sets. The evaluation process and the results of the study show that machine learning algorithms can be used effectively for prediction of bugs.**

***Keywords*—Static code analysis; software bug prediction; software metrics; machine learning techniques**

I. INTRODUCTION

Due to the increasing size, complexity of software products and inadequate software testing no system or software can claim to be bugs free. There are many activities related to software testing such as implementing processes, procedures, and standards that must be carried out in a specific sequence to ensure that quality objectives are achieved or testing a product for issues such as software bugs. There are different classifications of bugs in software testing like Major defect: a defect, which will cause an observable product failure or deviation from functional requirements. Minor defect: a defect that will not cause a failure in execution of the product. Fatal defect: a defect that will cause application/system crash or close abruptly. Bugs can also be classified into functional defects, performance defects, usability defects, compatibility defects, security defects, etc. The use of analytical methods to check and review source codes is standard development practice. This process can be accomplished manually or automatically using static code analysis tools, dynamic code analysis tools, etc. Recently a lot of tools evolved for static code analysis, to provide a truly practical, value added solution to many of the problems that software development organizations face. But there are numerous false positives and false negatives results, which make these tools hard to be used in practice. So, there must be found another methodology or approach for static code analysis such as Machine Learning (ML) algorithms [1], [9], [12]. Software bugs usually appear during software development process. Software bugs are often difficult to detect or identify, and developers spend a large amount of time locating and fixing them. As well, some bugs cannot be detected at an early phase of development. To relieve the issue of bug fixing, the researchers did many extensively studies for bug prediction. Many machine learning (ML) driven prediction models have been built and tested on various basis. The process of software bug report is an important part of software maintenance, but the process of bug reports assignment can be very expensive in large software development projects, where a lot of studies suggest automating bug assignment approaches using machine learning in open-source software. Software Bug Prediction (SBP) plays a vital and important role in the process of improving software product quality. SBP is a process of generating machine learning models (classifiers) to predict software (code) defects based on historical data. The most recent methodologies used to predict software bugs are supervised(classification)machine learning models, and with recent advances in machine learning techniques, new models have emerged that have enhanced performance and capabilities in predicting software bug [2]. Classification is a major task of data analysis using machine learning algorithms that allow the machine to learn associations between instances and decision labels, from which an algorithm builds a model to predict the labels of new instances for a specific sample data. In machine learning, classification can be categorized into three types: binary (yes or no), multi-class, and multi-label classification [5], [25]. To build a dataset containing useful buggy code element characterization information, we chose Promise Repository dataset that stores software metrics along with bug information for many projects, these datasets were collected from real software projects by NASA [26]. The objective of this study is to investigate the previous studies that used most effective machine learning techniques for software bug prediction. In this paper, four supervised machine learning models are identified and utilized on four different datasets to evaluate the Machine learning algorithms capabilities in software bug prediction. The paper compares the proposed models based on various performance measures like accuracy, precision, recall, F1-score and ROC curves. The structure of this study is organized as follow. Section 2 presents a discussion on software bug prediction by analyzing static code analysis. An overview of the machine learning techniques is presented in Section 3. After that, the literature review is presented in Section 4. Section 5 presents our research methodology. Section 6 presents software metrics and data sets. An overview of the selected machine learning classifiers and their evaluation is presented in Sections 7 and 8. Section 9 presents the experimental results and discussion followed by conclusions and future work in the Section 10.

II. Software Bug Prediction by Analyzing Static Code

Static code analysis is a method of analyzing software code without its execution to find potential problems like defects or bugs issues that might arise at runtime to check the quality of source code and addressing weaknesses in the program code through evaluating and correct source code based on some factors like structure, content, and documentation. There are many commercial and open source tools developed for static code analysis [3], [24]. These tools remove the unnecessary fuzz from source code and perform some automated checks to improve and ensure a certain level of quality. This can be performed very early in the development process, during this procedure the code must pass many formal tests to be considered bug free. There exist several ways of analyzing static code by exploiting the natural language found within a program's text based on compliance with different coding standards. These types of analysis may be manual, which is usually very time consuming like code inspections, or automated using one or more tools. Software Bug Prediction (SBP) considers a vital activity during software development and maintenance. SBP is a methodology related to figure out bugs in the software module by considering software metrics as a parameter [4]. Numerous studies have confirmed that machine learning techniques are suitable techniques for predicting software bug to identify defective software code [5], [6], [9]. Bug reports are basic software development tools which describe software bugs, especially in open-source software [7], [30]. To warranty the quality of software, many projects use bug reports to gather and record the bugs reported [8]. The bugs classified into two classes: intrinsic bugs refer to bugs that were introduced by one or more specific changes to the source code and extrinsic bugs refer to bugs that were introduced by changes not recorded in the version control system [5], [18]. Several techniques have been developed over the years to automatically detect bugs in source code. Often, these techniques depend on formal methods program analysis. Many studies in literature use code features as input for machine learning algorithms to perform bug prediction. The most machine learning algorithms that can be used to detect software bugs is classification techniques [10].

III. Machine Learning Techniques

Machine learning is an area of research where computer programs can learn and get better at performing specific tasks by training on historical data [2]. Machine learning algorithms can be applied to analyze data from different perspectives to allow developers to obtain useful information [10], [38]. High quantities of data are needed to develop machine learning models-based prediction [11], [31], [33]. Machine learning algorithms build models from training examples, which are then used to make predictions when faced with new examples. Supervised learning is a type of machine-learning algorithm that builds a prediction model by training the labeled data to execute the prediction task. The goal of supervised machine learning algorithms is to develop an inferring function through concluding relationships between independent variables(inputs) and dependent variables(outputs) of the training datasets [5], [27]. Classification is a method uses a data mining or machine learning approach classify the data, classification techniques deal with a software component, named classifier, this classifier invoked with inputs (features). Features are extracted from the training data examples as text, numbers, or nominal values. Bug prediction is one application of machine learning that aims to identify critical pieces in source code potential contain defects. This process can be used in software projects to earning insights into how and where bugs happen to enhance software quality.

IV. Literature Review

Software bug prediction is one of the most popular research areas in software engineering. The major aim of the software bug prediction is to detect bugs in software modules by considering software metrics as input (parameters). The research described in this paper presents a comprehensive study on machine learning techniques for software bug prediction. The following subsection covers the recent literature related to bug prediction. Considerable research has been performed on software bug prediction using machine learning techniques. For example, Wang et al. in [1] proposed a combination approach of contexts and neural network to detecting bugs. The results show that the tool can have a relative improvement up to 160% on F-score. Also, the tool can detect 48 true bugs in the list of top 100 reported bugs. Jonsson et al. in [2] evaluated automated bug assignment techniques that are based on machine learning classification. The results of study show that the prediction of accuracies is between 50% and 90% when large training sets are used. Chappell et al. in [3] presented report on using machine learning techniques for finding bugs in C programs. Hammouri et al. in [5] presented machine learning model for software bug prediction. The experiment was conducted on the basis of three supervised machine learning algorithms Naïve Bayes, Decision Tree, and Artificial Neural Networks to predict future software bugs based on historical data. The results show that the use of machine learning algorithms is effective and leads to a high rate of accuracy. The comparison results showed that the Decision Tree (DT) classifier has the best results over the others. Kumar Pandey et al. in [6] conducted compare various Bayesian network classifier and how they are useful for bugs prediction and random forest. The experimental results revealed that the Bayesian network is better than random forest. Meenakshi et al. in [7] proposed various ML models for software bug prediction. The experiment results demonstrated that the machine learning techniques are efficient and suitable approaches to predict the future software bugs and the comparison of results showed that the DT classifier has the best results over the others. Un-

Nisa Uqaili et al. in [8] proposed an approach to classify different types of bugs according to their severity and priority basis. They applied three supervised machine learning models (Naïve Bayes, Random Forest, and Multilayer Perceptron) for prediction of fault prone. The experimental results showed that the Random-Forest (RF) method better than other techniques of machine learning. Aleem et al. in [10] conducted study to a comparative the performance of some machine learning algorithms for software bug prediction. The results showed most of the applied machine learning techniques performed well on software bug prediction. Islamet et al. in [11] presented an empirical study using deep learning libraries to explore the bugs in software. They conducted 2716 comprehensive bug characteristics studies to identify the bug types and root causes of bugs. The study found that the most severe bug types in deep learning software are data bug and logic bug, where appearing more than 50% of the times and main causes of these bugs are incorrect model parameter and structural inefficiency. Sharma et al. in [13] proposed a new approach of creating a dictionary to classify critical terms and determine severity using two machine learning algorithms (Naïve Bayes Multinomial and K-nearest neighbor algorithms), and the results were evaluated based on two performance measures (accuracy and accuracy). The results demonstrated that the K-nearest neighbor classifier performs better Naïve Bayes Multinomial classifier to classify the severity of the bug Table I illustrates techniques used in previous studies on machine learning-based software bugs prediction. Bold number indicates comparative studies, capital and bold X shows the classifier giving the best results.

TABLE I. ML TECHNIQUES USED IN PREVIOUS STUDIES FOR SOFTWARE BUGS PREDICTION

Reference	**Machine Learning techniques**							
	DT	**NB**	**ANNs**	**RF**	**SVM**	**DL**	**K-NN**	**LR**
[1]			x					
[3]			x					
[4]		x						
[5]	**X**	x	x					
[6]		x						
[7]	**X**	x						
[8]		x	x	**X**				
[10]	x	x	**X**	x	**X**			
[11]						x		
[12]		x					x	
[13]		x						
[16]		x	x		x		x	
[18]		x		x	x			**X**

V. RESEARCH METHODOLOGY

The main objective of this study is to identify and analyze the latest studies that use machine learning techniques for software bug prediction. A literature review has been used as a research methodology in this study as it is a defined and methodical way of identifying, evolution, and analyzing published literature to investigate the research questions.

A. Study Selection

There are a lot of criteria to identify the relevant studies in this study and papers collected and reviewed by year of publication as it is shown in Fig. 1. For a paper to be included in this study, it must meet various inclusion criteria.

- Studies that suggest and discuss the use of machine learning techniques to predict software bugs.
- Studies that motivate and discuss the benefits of using machine learning techniques for software bug prediction.
- Studies that provide an empirical basis for the results and have been published in a high-quality journal or in conference proceedings.

B. Research Questions

This study aims to establish a starting point for future research for software bug prediction and simultaneously provide practitioners with a summary of most relevant work done in the area of software bug prediction uses machine learning techniques to heel and allow picking machine learning techniques that suits them. The research questions identified in this context are given in Table II.

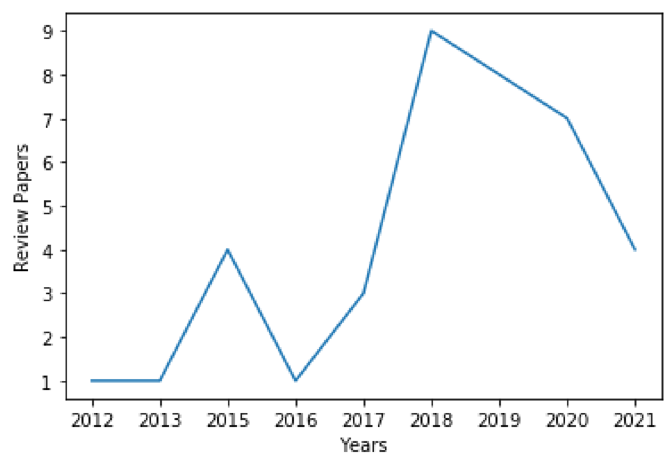

Fig. 1. Number of Papers Collected and Reviewed by Year of Publication.

TABLE II. RESEARCH QUESTIONS

RQ#	**Research Question**	**Motivation**
RQ1	Which ML models have been used for software bug prediction?	Identify the machine learning models commonly being used for software bug prediction.
RQ2	How these models have been trained and what languages have been used?	To find out how these models were trained and what languages are used.
RQ3	Which performance measures are used for software bug prediction?	Assess the performance of the machine learning techniques for software bug prediction.
RQ4	What the conclusions can we draw about the efficiency of machine learning algorithms used in predicting software bug from results presented in the selected studies?	Identify the efficiency of machine learning algorithms used in predicting software bug from results presented in the selected studies.

1) RQ1: Which ML models have been used for software bug prediction?: To answer this research question, this study identified the machine learning models commonly being used for software bug prediction in previous studies as shown in Fig. 2, and these models are:

- Decision Tree is a popular learning method used in data mining and machine learning for the purpose of regression and classification. It refers to a hierarchal model or a tree with decision nodes that have more than one branch and leaf nodes that represent the decision. Each node in a decision tree represents a feature in an instance to be classified, and each branch represents the value thresholds the contained nodes can assume. Instances are categorized beginning at the root node and sorted based on their attribute values [5], [29].
- Naïve Bayes (NB) is a supervised learning algorithm and defines as simple probabilistic classifier and efficient based on Bayes theorem with independence assumption between the features, this means that the Naive Bayes classifier is based on estimating the probabilities of the unobserved node, based on the observed probabilities [5], [22].
- Artificial Neural Networks (ANNs): ANNs are machine learning models or nonlinear classifiers used to model complex relationships between inputs and outputs for classification purposes. An ANN model contains multiple units (layers) for information processing which are known as neurons. The layers are typically named the input layer, hidden layer, and output layer [5]. When implementing a neural network, a set of consistent training values must be available to set up the expected operation of the network and a set of validation values to validate the training process [14].
- Random Forest is one of the most utilized models, due its effortlessness and the way, which it can be utilized for both characterization and relapse assignments. It is an adaptable and simple to utilize machine learning calculation, even without hyper-parameter tuning [23].
- Support Vector Machine (SVM): SVM is one of the regulated machine learning models. It is a comparatively novel learning approach used for binary classification. The primary role is to discover a hyper-plane, which divide the dimensional data completely into two categories [15], [32].
- Deep Learning (DL): DL is one of an artificial intelligence function that mimics the workings of the human brain. It allows and helps to solve complex problems with using a data set that is very diverse, unstructured, and interconnected [40].
- K-Nearest Neighbor define as a simple supervised classification algorithm in which an object is classified by looking at the K nearest objects and by choice most frequently occurring class [28].
- Logistic Regression (LR): LR is a statistical classification technique which is based on maximum likelihood estimation. It is meant for predicting the likelihood of an entity belonging one class or another class [16], [28], [37], [39].

2) RQ2: How these models have been trained and what languages have been used? To answer this research question, the essential issue of software bug prediction with machine learning techniques is how train and test the model [17]. A large and representative data set is the basis for training and testing machine learning models. So, in the literature review and in our experimental study, different and large datasets, and different programming languages such C, C++ and Java has been used to training machine learning models.

3) RQ3: Which performance measures are used for software bug prediction? To answer this research question, several measures are used for gauging the performance of different machine learning models. These performance measures are used for comparing and evaluating models developed using various machine learning techniques. A depiction of the number of studies using each performance measures is used in Fig. 3. The most used performance metric is accuracy, which is closely followed by recall, precision, and F1-score, and some less commonly metrics are H-measure, Area Under the Curve (AUC) and Receiver Operating Characteristics (ROC) curve.

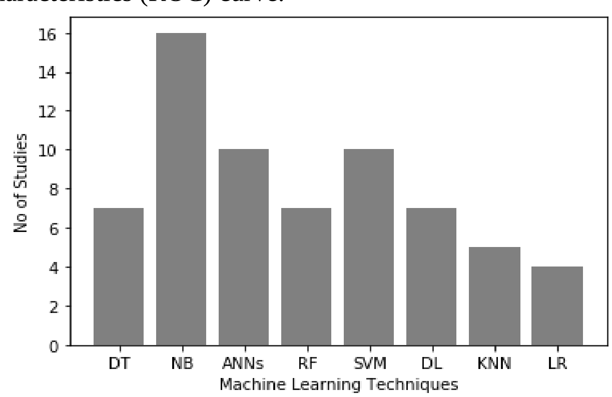

Fig. 2. Number of Studies across ML Techniques based on Classifications.

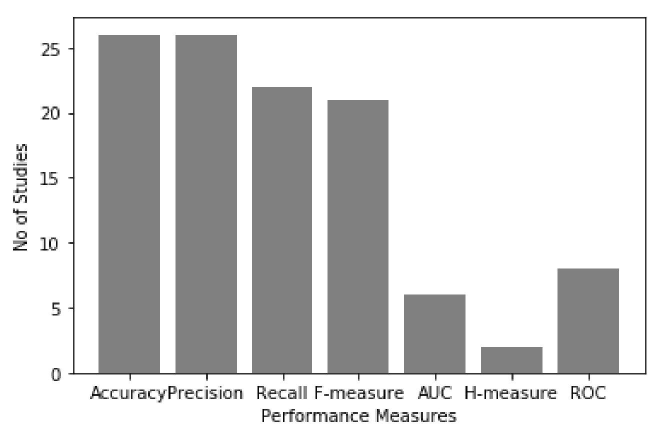

Fig. 3. Studies using different Performance Measures for SBP.

4) RQ4: What the conclusions can we draw about the efficiencies of machine learning techniques for software bug prediction from results presented in the selected studies?: To answer this research question, this study evaluates the best machine learning techniques for devolving an effective model for software bug prediction through evaluating the presented software bug prediction models in previous studies. Different machine learning techniques have different characteristic like speed, accuracy, interpretability, and simplicity. This study focused on the studies that applied machine learning algorithms and performance measures that most used. Looking at the results achieved in the literature review and the results achieved in our study, machine learning techniques are well applicable to static code analysis for software bug prediction.

VI. Software Metrics (Features) and Datasets

Software metrics are a quantitative and standard measure of some property of software that assigns numbers or symbols to attributes of the measured entity. Software metrics can be used to collect information regarding structural properties of a software design which can be further statistically analyzed, interpreted and linked to its quality. In software comprise complexity, cohesion, and coupling related metrics can be measured during the software development phases such as design or coding and it also used to calculate the quality of software [19], [34], [36]. Software metrics can be classified to static code metrics and process metrics. Static code metrics can be directly extracted from source code, like Lines of Code (LOC), Cyclomatic Complexity Number (CCN). Object oriented metrics is a subcategory of static code metrics, like Depth of Inheritance Tree (DIT), coupling between Objects (CBO), Number of Children (NOC), and Response for Class (RFC). Process metrics can be extracted from Source Code Management system based on historic changes on source code overtime. Metrics can also be classified based on development phase of software life cycle, into source code level metrics, detailed design level metrics or test level metrics. Object-oriented metrics are often used to assess the testability, maintainability or reusability of source code [20], [35]. Commonly dataset that used for software bug prediction domain is promise repository dataset. To perform this experiment, the data is obtained from the publicly available and published data in defect prediction datasets that stored software metrics along with defect information of several projects, these datasets were collected from real software projects by NASA. These public domain datasets are used in this experiment because this is a benchmarking procedure of defect prediction research [17, 21]. To perform machine learning on the available source code, it is necessary to establish a set of features that can be extracted that contain the information needed. Many studies [4, 6, 7, and 14] use software metrics as independent variables to measuring the quality of software modules and build software bug prediction models. It is intuitive to think that the bug proneness of a module is correlated with its complexity; therefore, bug prediction studies usually employ product metrics to improve prediction accuracy. The projects used in this study were developed using different programming languages and include heterogeneous code metrics like Object-Oriented (OO) metrics, Halstead metrics, Lines of Codes (LoC), and McCabe complexity. Various defects detection methods like Black box probing, automatic formal methods, etc. And different machine learning models like linear regression, the M5' model tree learner and the J48 decision tree learner have been implemented in these projects [10]. Table III, Table IV shows the information about dataset, and software metrics (features).

TABLE III. Descriptions of Datasets (Projects) used in this Study

Projects	# Modules	% Defects	Language	Description
JM1	10885	19%	C	Real-time predictive ground system: Uses simulations to generate predictions.
PC1	1107	6.8%	C	Flight software for earth orbiting satellite.
KC1	2107	15.4%	C++	Storage management for receiving and processing ground data.
KC2	523	20%	C++	Software for science data processing.

TABLE IV. Descriptions of Software Metrics (Features) used in this Study

Metrics	Type	Description
Loc	McCabe	It counts the line of code in software module.
v(g)	McCabe	Measure McCabe Cyclomatic Complexity.
ev (g)	McCabe	McCabe Essential Complexity.
iv (g)	McCabe	McCabe Design Complexity.
N	Derived Halstead	Total number of operators and operands.
V	Derived Halstead	Volume.
L	Derived Halstead	Program length.
D	Derived Halstead	Measure difficulty.
I	Derived Halstead	Measure Intelligence.
E	Derived Halstead	Measure Effort.
B	Derived Halstead	Effort estimate.
T	Derived Halstead	Time Estimator.
Locoed	Line Count	Number of lines in software module.
Locomment	Line Count	Number of comments.
Loblank	Line Count	Number of blank lines.
Locodeandcomment	Line Count	Number of codes and comments.
uniq_op	Basic Halstead	Unique operators.
uniq_opnd	Basic Halstead	Unique operands.
total_op	Basic Halstead	Total operators.
total_opnd	Basic Halstead	Total operands.
BranchCount	Branch	Total Number of branch count.

VII. CLASSIFIERS USED FOR SOFTWARE BUG PREDICTION IN THIS STUDY

The next step after collecting datasets is using the collected datasets to train a machine learning models potential buggy modules as it is shown is Fig. 4. Four supervised machine learning algorithms will be analyzed and evaluated in this study, which are DT, NB, RF and LR. These algorithms were chosen because are the most algorithms used in previous studies.

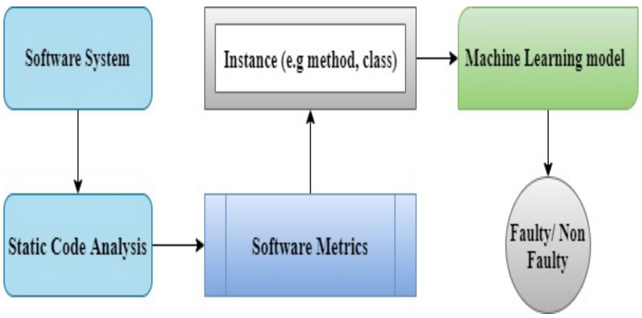

Fig. 4. Structure of Software Bug Prediction Model.

VIII. BUILDING AND EVALUATION OF PREDICTION MODELS

Most studies of software bug prediction divide the data into two sets: a training set and a test set. The training set is used to train the bug prediction models, whereas the testing set is used to evaluate the performance of the bug prediction models. After building the prediction model, we need to evaluate the performance of the model. To evaluate the performance of using machine learning models in software bug prediction in this study used a set of performance measures based on the confusion matrixes and ROC (Receiver Operating Characteristic) Curves. Confusion matrix(correlation matrix) is often used to describe the performance of machine learning models(classification methods) using a set of test data, correlation summarizes the results of the testing algorithm and provides a report of (1) True Positives (TP), (2) False Positives (FP), (3) True Negatives (TN), and (4) False Negatives (FN). ROC curves are plots the false positive rate on the x-axis and true positive rate on the y-axis over all possible or potential classification thresholds. The subsections bellow describes the confusion matrix and performance measures applied as it is shown in Table V and equations.

- Accuracy: Accuracy is the ratio of true results that calculated as the sum total of true positive and true negative instances divided by 100. The top (maximum) accuracy is 1, whereas the low (minimum) accuracy is 0. Accuracy can be computed by using the following formula:

$$\text{Accuracy} = \frac{(\text{TP} + \text{TN})}{(\text{TP} + \text{TN} + \text{FP} + \text{FN})} \tag{1}$$

- Precision: Precision is defined as the number of true positive predictions divided by the total number of positive predictions or fraction of true positive and predicted yes instances. The top (maximum) precision is 1, whereas the low (minimum) is 0 and it can be calculated as:

$$\text{Precision} = \frac{\text{TP}}{(\text{TP} + \text{FP})} \tag{2}$$

- Recall: Recall is the number of positive predictions divided by the total number of positives or defined as the fraction between true positive instances and actual yes instances. The top (maximum) recall is 1, whereas the low (minimum) is 0. The formula of recall given below:

$$\text{Recall} = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{3}$$

- F1-score: F1-score is weighted harmonic mean of precision and recall or defined as the fraction between product of the recall and precision to the summation of recall and precision parameter of classification, it is used to combine the recall and precision measures in one measure to compare different machine learning algorithms. F1-score formula is given below:

$$\text{F1} - \text{score} = \frac{(2 * \text{Recall} * \text{Precision})}{(\text{Recall} + \text{Precision})} \tag{4}$$

TABLE V. THE CORRELATION MATRIX

Predicted	**Actual**	
	Class X	Class Y
Class X	TN	FP
Class Y	FN	TP

IX. RESULT AND DISCUSSION

This study aimed at improving the understanding of the process of software bug prediction especially using supervised machine learning techniques. In the literature review, several papers were found that discussed machine learning models for predicting software bugs that classify the defective and non-defective module. It was observed in the RQ1 analysis that most of the machine learning techniques used in software bug prediction are NB, ANNs, and SVM. As it is noted in the RQ2 analysis that studies used different performance measures. The experiment of this study was performed in PYTHON environment to evaluate four machine learning algorithms: DT, NB, RF and LR. The evaluation process is implemented with real datasets. Experimental results are collected and evaluated based on various performance measures (accuracy, precision, recall, F1-score and ROC Curves). Results demonstrated that the machine learning algorithms are efficient approaches to predict software bugs. The comparison results demonstrated that the Decision Tree (DT) and Random Forest (RF) classifiers have the best results. Tables VI to IX show the performance of proposed models on the four data sets based on all performance measures. The maximum (best) accuracy value is 99%, which was achieved by Decision Tree (DT) and Random Forest (RF) models in JM1, PC1and KC1 datasets. The maximum (best) precision value is 99%, which was achieved by Decision Tree (DT) and Random Forest (RF) models in JM1, PC1and KC1 datasets. The maximum (best) recall value is 100%, which was achieved by Decision Tree (DT) and Random Forest (RF) models in all datasets. The maximum (best) F1-score value is 99%, which was achieved by Decision Tree (DT) and Random Forest (RF) models in

PC1 dataset. The average accuracy of the proposed models on the four data sets is shown in Fig. 5 and Fig. 6. As shown, the two ML models Decision Tree (DT) and Random Forest (RF) achieved a high average accuracy rate. The average value for the accuracy rate in all datasets for the two models is over 98.5% on average. The minimum value appears for Naive Bayes (NB) model in the JM1 dataset, because the data set is small and the Naive Bayes (NB) model needs a large data set in order to achieve a high accuracy value. Fig. 7 to Fig. 10 presents the ROC Curves of proposed models on the four data sets. The results show that Decision Tree (DT) and Random Forest (RF) models have better values than Naive Bayes (NB) and Logistic Regression (LR) models. For evaluating the effectiveness of the proposed models, in Tables X and XI we have compared the results of our study with the results of three others studies [4, 7, and 10] which used the same dataset and different performance measures (Accuracy, Precision, Recall, and F1-score). The results showed that our proposed models performed better than others models. After a comprehensive study of Machine Learning techniques, there must be a deterministic strategy for selecting machine learning techniques to predict software bugs.

TABLE VI. PERFORMANCE MEASURES OF THE PROPOSED MODELS OVER JM1 DATASET

proposed model	Performance measures			
	Accuracy	**Precision**	**Recall**	**F1-score**
DT	**0.99**	**0.99**	**1.00**	**0.99**
NB	0.80	0.81	0.97	0.89
RF	**0.99**	**0.99**	**1.00**	**0.99**
LR	0.81	0.82	0.99	0.89

TABLE VII. PERFORMANCE MEASURES OF THE PROPOSED MODELS OVER PC1 DATASET

proposed model	Performance measures			
	Accuracy	**Precision**	**Recall**	**F1-score**
DT	**0.99**	**0.99**	**1.00**	**1.00**
NB	0.91	0.94	0.96	0.95
RF	**0.99**	**0.99**	**1.00**	**1.00**
LR	0.93	0.94	0.99	0.96

TABLE VIII. PERFORMANCE MEASURES OF THE PROPOSED MODELS OVER KC1 DATASET

proposed model	Performance measures			
	Accuracy	**Precision**	**Recall**	**F1-score**
DT	**0.99**	**0.99**	**1.00**	**0.99**
NB	0.85	0.88	0.96	0.92
RF	**0.99**	**0.99**	**1.00**	**0.99**
LR	0.85	0.87	0.96	0.92

TABLE IX. PERFORMANCE MEASURES OF THE PROPOSED MODELS OVER KC2 DATASET

proposed model	Performance measures			
	Accuracy	**Precision**	**Recall**	**F1-score**
DT	**0.98**	**0.98**	**1.00**	**0.99**
NB	0.83	0.83	0.98	0.90
RF	**0.98**	**0.98**	**1.00**	**0.99**
LR	0.84	0.86	0.96	0.91

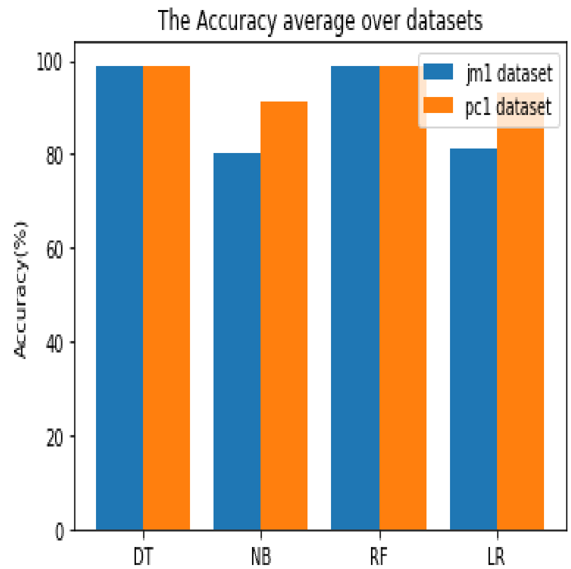

Fig. 5. Average of Accuracy Measure of Models across the JM1 and PC1 Dataset.

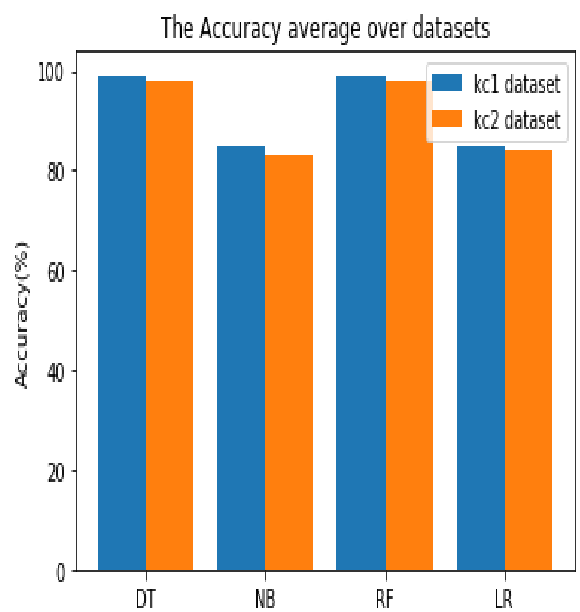

Fig. 6. Average of Accuracy Measure of Models across the KC1 and KC2 Dataset.

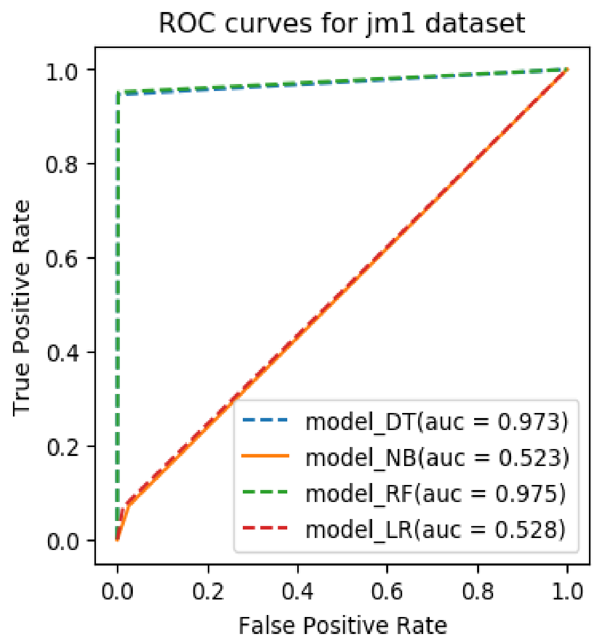

Fig. 7. Comparison of ROC Curves for Models across the JM1 Dataset.

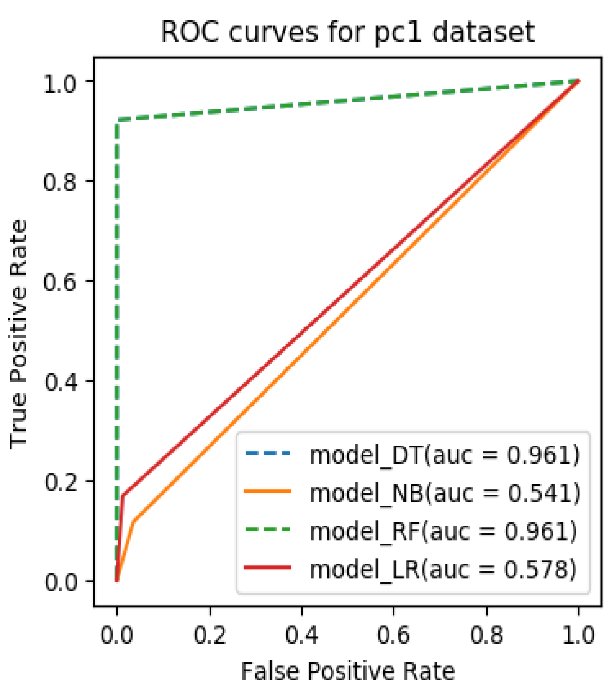

Fig. 8. Comparison of ROC Curves for Models across the PC1 Dataset.

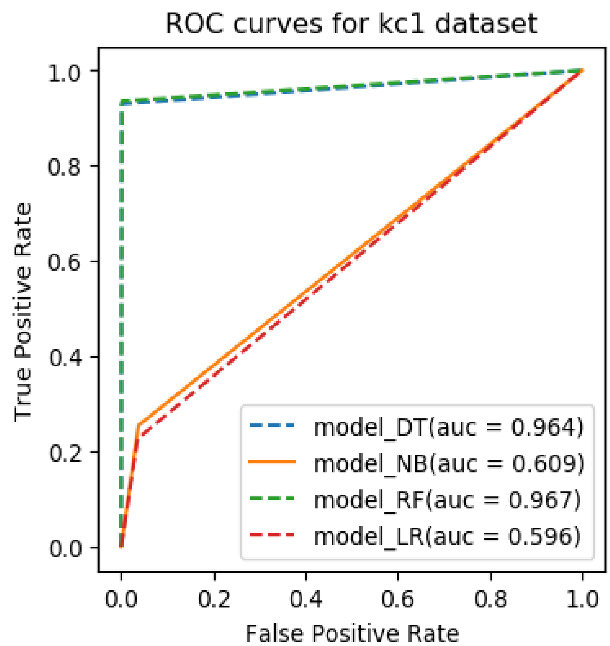

Fig. 9. Comparison of ROC Curves for Models across the KC1 Dataset.

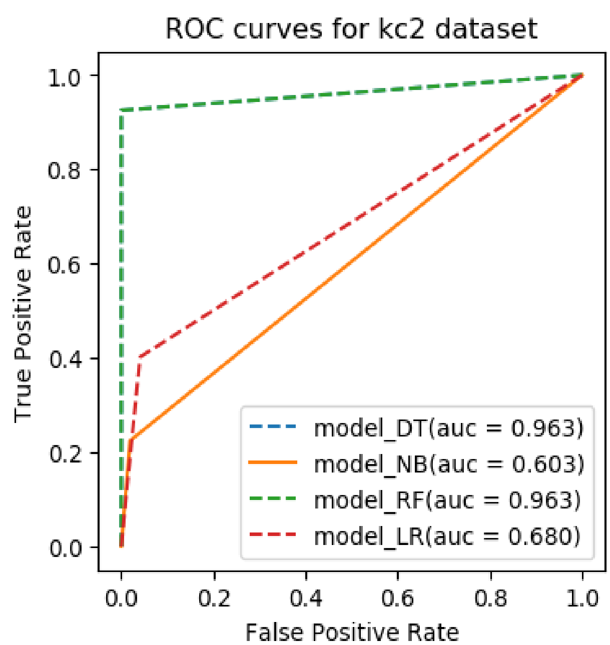

Fig. 10. Comparison of ROC Curves for Models across the KC2 Dataset.

TABLE X. COMPARING THE RESULTS OF OUR STUDY WITH THE RESULTS OF STUDIES WHICH USES THE SAME DATASET AND ALGORITHMS ACROSS THE JM1 AND PC1 DATASET

JM1 dataset					
Performance measure	**ML models**	**Studies**			
		First Study	**Second Study**	**Third Study**	**Our study**
Accuracy	DT	-	-	0.81	**0.99**
	NB	-	-	0.81	**0.80**
	RF	-	-	0.82	**0.99**
F1-score	DT	-	-	0.90	**0.99**
	NB	0.75	-	0.89	**0.89**
	RF	0.76	-	0.90	**0.99**
	LR	0.74	-	-	**0.89**
pc1 dataset					
Accuracy	DT	-	-	0.93	**0.99**
	NB	-	-	0.88	**0.91**
	RF	-	-	0.93	**0.99**
F1-score	DT	-	-	0.97	**1.00**
	NB	0.89	-	0.94	**0.95**
	RF	0.91	-	0.97	**1.00**
	LR	0.91	-	-	**0.96**

TABLE XI. COMPARING THE RESULTS OF OUR STUDY WITH THE RESULTS OF STUDIES WHICH USES THE SAME DATASET AND ALGORITHMS ACROSS THE KC1 AND KC2 DATASET

kc1 dataset					
Performance measure	**ML models**	**Studies**			
		First Study	**Second Study**	**Third Study**	**Our study**
Accuracy	DT	-	-	0.84	**0.99**
	NB	-	0.82	0.82	**0.85**
	RF	-	-	0.85	**0.99**
Precision	NB	-	0.80	-	**0.88**
Recall	NB	-	0.83	-	**0.96**
F1-score	DT	-	-	0.92	**0.99**
	NB	0.82	0.81	0.90	**0.92**
	RF	0.82	-	0.92	**0.99**
	LR	0.81	-	-	**0.92**
kc2 dataset					
Accuracy	DT	-	-	0.82	**0.98**
	NB	-	-	0.84	**0.83**
	RF	-	-	0.82	**0.98**
F1-score	DT	-	-	0.89	**0.99**
	NB	0.80	-	0.90	**0.90**
	RF	0.76	-	0.89	**0.99**
	LR	0.79	-	-	**0.91**

X. CONCLUSION

Software bug prediction is very important field in static code analysis to improve software quality and reliability. It is an approach, in which a prediction model is constructed for the purpose of predicting future software defects based on historical data using some software metrics. Many approaches have been presented using various datasets, various metrics, and various performance measures. The aims of this study are successfully achieved. The aims are evaluate and present comprehensive study on machine learning techniques have been used for software bug prediction in recent years and apply the best techniques for software bug prediction in this study. To compare and evaluate the performance of the proposed models, we used different performance measures. The results concluded that ML techniques are gaining interest in software bug prediction, to improve the efficiency of bug detection. Four NASA public datasets were chosen for this experiment and analyze the performance of models. The experimental results revealed that the DT and RF classifiers are better than others classifiers. Static code analysis requires further research to identify and detect of software bugs and several machine learning techniques can be used to improve results. As a future work, we plan to introduce other machine learning techniques with data balancing techniques to improve the accuracy for predicting software bugs.

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The Effect of Adaptive Learning Rate on the Accuracy of Neural Networks

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Abstract*—Learning rates in gradient descent algorithms have significant effects especially on the accuracy of a Capsule Neural Network (CNN). Choosing an appropriate learning rate is still an issue to date. Many developers still have a problem in selecting a learning rate for CNN leading to low accuracies in classification. This gap motivated this study to assess the effect of learning rate on the accuracy of a developed (CNN). There are no predefined learning rates in CNN and therefore it is hard for researchers to know what learning rate will give good results. This work, therefore, focused on assessing the effect of learning rate on the accuracy of a CNN by using different learning rates and observing the best performance. The contribution of this work is to give an appropriate learning rate for CNNs to improve accuracy during classification. This work has assessed the effect of different learning rates and came up with the most appropriate learning rate for CNN plant leaf disease classification. Part of the images used in this work was from the PlantVillage dataset while others were from the Nepal database. The images were pre-processed then subjected to the original CNN model for classification. When the learning rate was 0.0001, the best performance was 99.4% on testing and 100% on training. When the learning rate was 0.00001, the highest performance was 97% on testing and 99.9% on training. The lowest performance observed was 81% accuracy on testing and 99% on training when the learning rate was 0.001. This work observed that CNN was able to achieve the highest accuracy with a learning rate of 0.0001. The best Convolutional Neural Network accuracy observed was 98% on testing and 100% on training when the learning rate was 0.0001.

Keywords*—*CNN; ConvNet; learning rate; gradient descent

I. Introduction

Deep learning has been used over time for plant leaf disease detection and classification. Some of the researchers who have used deep learning include [29,30,31,32,33,34,35,36,37,38,39]. Capsule neural networks (CNN) are a regularly used neural network structure that has significant effects on deep learning, particularly in computer vision studies. CNN's have attained superhuman levels in different computer task categories, for example, object detection, classification, incidence segmentation, semantic segmentation, and parsing. The learning rate is viewed as the absolute hyper-parameter to tune and remarkably influence model training with gradient descent algorithms [1, 2]. Studies have come up with several learning rate techniques including inverse square root decay, linear decay, exponential decay, and cosine decay [3, 4]. These learning rates have varying procedures that are based on an optimization problem. One of the limitations involves the selection of a suitable learning rate for a given application.

Practically, researchers have adopted a trial-and-error method for various learning rates alongside diverse hyper-parameters, which is a very tedious process [5]. This paper utilizes a regulator that adapts three learning rate schedules of 0.001, 0.0001, and 0.00001. Existing learning rate schedules adopt predefined parametric learning rate changes, which are fixed regardless of prevailing training dynamics. The predefined parametric learning rate changes have a limited flexibility and may not be improved for the training dynamics of various high dimensional and non-convex advancement issues [6]. The context for this work provides adaptive meta-learned learning rates that dynamically adjust to current training. The process of training a neural network using an algorithm, for example, the error back-propagation [1, 2, 3, 4] is normally time-consuming, especially when working on complex problems. These types of algorithms naturally have a learning rate parameter that controls the extents by which the weights can change based on an observed error that was noted on the training set.

Learning rate schedules can dramatically affect the accuracy of the results. Therefore, the process of choosing learning rates using training algorithms can be problematic especially when there is no guiding value for specific tasks. Various algorithms have been used to tune the learning rate parameters [6, 7, and 8], yet such strategies generally have failed to concentrate on refining the resulting accuracy. Most of the experts in neural networks use the highest learning rates that allow merging. However, when learning rates are set too high, it causes unwanted divergent behavior in the loss function. Hence when the highest learning rates are applied to complex and large problems, there is a negative effect on the training process and accuracy. On the other hand, when the learning rate is set too low, the training progress will be very slow because very small updates are made to the weights of the work [9]. So there is a need to balance and there is no better way to do that other than to test several learning rates and observe their performances. This work adopts the use of online training instead of batch training. This is because batch training needs more time compared to online training with no corresponding improvement inaccuracy [5]. This paper aims to investigate the effect of learning rate on the accuracy of CNN's as applied in plant disease detection. Since Tensor flow recommends a learning rate of 0.001, this works started by using that learning rate and observed a low percentage of 84%

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accuracy in testing. It is from there that this work focused on reducing the learning rate further to 0.0001 and then to 0.00001. A total of 24 experiments were conducted for plant leaf disease classification using the three learning rates and 0.0001 gave the best classification results of 99.4% accuracy on testing and 100% on training.

II. Related Work

Hyperparameters such as batch size need adjusting before capsule neural network training for image classification. Studies on the effect of batch size and learning rates on neural network accuracy have been conducted. The studies have tried to determine the more efficient network performances related to learning rates and the magnitude of batches.

According to [10] the default number batch size should be 32. The author noted that a large batch size and high learning rates speed up the process of network performance but reduce the number of updates needed to reach convergence. Batch sizes do not affect the performance of the neural network but influence the convergence time. Masters and Luschi [11] studied the effect of batch sizes on ImageNet, CIFAR10, and CIFAR100 datasets for two architectures of ResNet and AlexNet. The batch sizes ranged between 21 and 211. The results showed that the best accuracies were achieved from batch sizes that ranged from 2 and 32. The study concluded that large batch sizes are not efficient compared to small batch sizes. Radiuk [12] also studied the effect of batch size on network performance for the classification of images using CIFAR-10 and MNIST datasets for the LeNet architecture. The study used two learning rates of 0.0001 (CIFAR-10) and 0.001 (MNIST). The results showed that the highest accuracy was obtained from the largest batch size with a lower learning rate of 0.0001. This showed that batch size and learning rates affect the performance of neural networks.

Several studies have proposed improved update schedules for gradient descent algorithms [7, 8, 9, 13, 14, and 15]. In [7], the need for direct learning of the gradient descent updates through the use of the long short-term memory (LSTM) network was proposed. Hyper gradient tends to assume the learning rate derivative and subsequently updates it according to its gradient [8]. Z. XU [9] proposed a reinforcement learning-based framework that can auto-learn an adaptive learning rate schedule according to the existing information from historical training. This method puts into consideration the whole training history while presenting a comprehensive interpretation. Daniel [13] proposed the application of reinforcement learning (RL) with a focus on learning rate adaptation. This paper uses the learning rates as the action and the reward indicator include validation loss. Duchi et al. [14] used learning rate adaptation based on the weight and the total number of gradient squares and obtained some results. Kingma [15] used an exponentially decayed mean of historical gradients.

Neural Networks are models with progressive layers of neurons that have been in existence for quite a long time. They can be trained in both Supervised and Unsupervised [16] ways. In supervised training, a backpropagation algorithm was created in the 1970s [17]. This algorithm utilizes a gradient descent approach to compute the learning system of the neural network. A gradient descent approach is commonly used in neural networks to update parameters ($\lambda = \{1e^{-1}, 1e^{-2}, 1e^{-3}\}$). Such training is conducted to get to an optimum point where the loss is at its minimum and the expected and predicted values are almost similar [18]. Training a large neural network is a challenging task. Sebastian [19] established the Stochastic Gradient Descent (SGD) algorithm to accomplish an improved performance during the training time using variable learning rates. Such processes have been described as Adaptive Learning Rates/ Rate Scheduling [26]. Larger learning rates have also been used by [27], who used a learning rate of 0.4 and achieved 75% accuracy. The results show a low accuracy rate which most likely was caused by the high learning rate. Purnomo [28] used 0.01 and observed that this learning rate led to low accuracies

III. Convolutional Neural Networks (ConvNets)

When convolutional neural networks in Fig. 1 are applied to disease detection, models demonstrate great performance. The discussion below shows some great materials showing the use of convolutional neural networks in the detection and classification of plant diseases.

The authors in [59] used LeNet architecture [Le89] architecture with CNN for the classification of banana leaf disease. The images used were from Plantvillage which were from homogeneous backgrounds. The results obtained, according to the authors were good. The challenges experienced were that in some splits, the model took more time to converge, and practically, all the images cannot be from uniform backgrounds.

Researchers in [60] used the digital color image analysis discrimination method: The results were questionable because of the existence of other leaves or weeds. Segmentation is not fit to be used in the field because it will fail to effectively extract the leaf from its background hence inaccurate results. Alex Net and transfer learning were used by [61] to detect common rice plant anomalies using CNN. During the classification task, the approach never considered the specific class of diseases that may affect rice plants. The authors also used transfer learning on AlexNet which is a small and old CNN architecture. Authors in [62] used segmentation method in detecting soybean rust from multispectral images using CNN. The results were questionable because of the existence of other leaves or weeds. Segmentation is not fit to be used in the field because it will fail to effectively extract the leaf from its background hence inaccurate results. Author in [63] used segmentation with CNN and there was a lot of reliability on hand-crafted features such as color histograms, texture features, shape features, and SIFT that require expensive work and demand expert knowledge. The author in [64] used Gabor filter for feature extraction and Artificial Neural Network classifier for classification in real plant tomato leaf disease recognition. They used images from homogeneous backgrounds alone which practically is not true because there must be other plants and weeds in farms. The author in [65] used images from plant village alone and AlexNet architecture for plant disease detection and they lacked the accuracy of result because plant village dataset images have homogeneous backgrounds while under normal conditions, images from the field have heterogeneous backgrounds.

The authors in [65] utilized the convolutional neural network to detect disease in plant leaves. In the research, 54306 images and 14 different species of plants were used which later represented 26 diseases together with healthy leaves. Furthermore, the authors used segmented, greyscale, and colored images for model training and the accuracy was 99.35%. However, when tested on another dataset, the accuracy fell to 31.4%. Real-Time captured images have heterogonous backgrounds while the images from the plant village dataset have a homogenous background. The author in [66] used convolutional neural networks to recognize 13 plants of different species and detect disease in their leaves. All the images utilized by the author were secondary images fetched from the internet. Here, 15 classes were considered and one class for the healthy leaves the accuracy was measured at 88%. However, it was discovered that most of the images from the website were mislabeled and differed greatly from those taken from the field which later introduced a mismatch error. The researcher in [67] used 87,848 images with 25 different plant species and included healthy plants. AlexNet, Over feat, GoogleNet and AlexNet were utilized in the identification of plant leaf diseases from images captured from the field. The aim was to be able to match the plant and disease combination when a leaf image was provided. The datasets here contained images from the laboratory and field as well. The accuracy was found to be 99.53%. CNN gives some results, but they have two major challenges, Pooling layers, and Translation Invariance.

In research done by [68], CNN was used in detection and classification. The technique used was transfer learning while the coffee disease was classified as coffee leaf rust. The study used an android profiler in determining resource consumption. The researchers obtained some results. However, they observed loss of data through Pooling.

IV. Capsule Neural Networks (CNNs)

Capsules comprise neuron clusters that have vector activities [21]. The activities are a representation of different pose parameters while their vector lengths show the existence of specific neuron elements. Most CNNs problems are generally associated with the pooling layers. For capsule networks, issues of pooling layers are corrected using the "routing by agreement" procedure [22]. The procedure involves adding neuron outputs to parent capsules in a subsequent layer, though, they typically have different coupling coefficients. The output of the parent capsules is based on the prediction of an individual capsule. If a prediction is consistent with the actual output of the parent capsule, then there is an increase in the coupling coefficient between the two capsule layers. Using capsule *I* that has u_i as its output, the prediction of an individual capsule *i* for parent capsule *j* is as shown in equation 1.

$$\hat{U}_{j|i} = W_{ij}\, u_i \tag{1}$$

where, $\hat{U}_{j|i}$ is considered as the prediction vector of the *jth* capsule output from a different layer resulting from capsule *i*, and where W_{ij} is used as a weighting matrix after being learned using the backward pass. The SoftMax equation can after that be computed from the coupling coefficients c_{ij} as shown in equation 2.

$$c_{ij} = \frac{exp(b_{ij})}{\sum_k exp(b_{ik})} \tag{2}$$

Where the log probability is represented by b_{ij}, which is programmed initially as 0 before initiating the "routing by agreement" process. The computation for adding a vector neuron to the parent capsule *j* is shown in equation 3.

$$s_j = \sum_i c_{ij}\, \hat{U}_{j|i} \tag{3}$$

Subsequently, there is a need to use a non-linear equation (4) to prevent capsule vectors from producing more than one output and creating the final output of an individual capsule.

$$v_j = \frac{\|s_j\|)^2}{1+\|s_j\|^2}\frac{s_j}{\|s_j\|} \tag{4}$$

where, v_j is the output of capsule *j*, and s_j is the input vector. The "routing by agreement" process allows for an updating of the log probabilities considering the agreement set between v_j and $\hat{U}_{j|i}$. When the two capsule vectors are in agreement, then they will produce a larger inner output. Equation (5) shows an agreement a_{ij} that is necessary for the updating of coupling coefficients and log probabilities.

$$a_{ij} = v_j \,.\, \hat{U}_{j|i} \tag{5}$$

For equation 6, individual capsule k in the final layer is related to l_k, which is a loss function. The function adds high loss values on individual capsules that have long output instantiation parameters when there is a missing entity.

$$l_k = T_k\ max\ (0, m^+ - \|v_k\|)^2 + \lambda(1 - T_k)\ max(0, \|v_k\| - m^-)^2 \tag{6}$$

When class k exists, T_k is 1. Otherwise when class k is absent T_k is 0. Hyperparameters m^-, λ and m^+ are used before beginning the learning process, and they must be indicated.

V. Hyperparameters in Deep Learning

A. Learning Rate

While training neural networks, a hyperparameter that has a positive value ranging between 0.0 and 1.0 is utilized [5]. The parameter is known as the learning rate and can be configured. Learning rates help in taking control of the adaptation of the model to a given problem. The smaller the learning rate the more the epochs because the changes made to the weights will be small. Large learning rates attract few epochs due to high speed. When the learning rate is too high, model convergence is very fast while on the other hand when the learning rate is too small, the process might be stuck at some point. It is therefore important to carefully select the learning rate to get correct results. This, therefore, makes the learning rate the most important parameter when it comes to neural networks.

B. The Number of Layers that are Hidden

The topology or architecture of a network is controlled by the actual number of layers and the nodes that each hidden layer contains. During network configuration, the values of the parameters must be specified. Systematic experimentation is considered the most accurate way of configuring parameters for various modeling problems. It is only through running various experiments that the number of hidden layers required, can be determined.

C. Momentum

This is a technique utilized during the backpropagation stage to track preceding directions and store them as embedded processed data. This helps the model to learn and embed the direction of the previous weights and proceed towards the same direction in the next propagation.

D. Activation Function

The decision as to whether neuron activation should be done or not is done by the activation function. The action is completed through the calculation of weighted sum and bias addition. Non-linearity is introduced to the neuron output by activation functions. For good results, it is advisable to use ReLu activation for layers that are hidden and then use a sigmoid activation function in the final layer.

E. Mini-batch Size

While using a very large dataset, it is challenging to feed a neural network with all of it. Therefore, it is a good practice to subdivide data into smaller sizes or group them into batches. This helps because each time the algorithm trains itself, a batch of the same size will be trained. If the batch sizes are too big, however, it may result in a model that is overgeneralized and data won't fit well.

F. Epochs

Epochs represent the number of times the dataset will be trained by the used algorithm during training. The number varies with data or task one is facing and there is no predefined number of epochs in any neural network. The idea is to introduce a condition that stops the epochs when the error is near zero or just starts with a lower number of epochs.

G. Dropout

Dropout allows the removal of some nodes in cases where the neural network is very heavy and cannot train well. The action is performed during the training stage and helps remove redundancies that may occur due to congestion.

VI. Proposed Work Methodology

In deep learning there are generally two basic parameters; hyper-parameters and machine learnable parameters (MLP). While training a particular dataset in any model, algorithms used in that model can estimate MLP on their own. On the other hand, Hyperparameters are assigned by data scientists or engineers in form of values. These values help in tuning the model and control how algorithms can learn. Learning rate is denoted by 'α'. In this work, the learning rate used is known as adaptive learning rate whereby the increase or decrease in learning rate is based on the gradient value of cost function (*CF*). Equation 7 below was used in the calculation of learning rates.

$$\propto_n=\frac{\propto_0}{\sqrt{s_n}} \tag{7}$$

where, the initial learning rate is denoted by *0* while the momentum factor (MF) is denoted bys_n. The number of epochs is denoted by *n*. MF was calculated using Equation 8 below:

$$s_n = [\gamma s_{n-1} + (1\text{-}\ \gamma)\frac{\partial CF}{\partial \beta}]\text{n} \tag{8}$$

where, γ is the hyperparameter and s_n is exponentially weighted gradient average. Here values of all the gradients were considered including those from previous epochs. The major contribution of this work is to demonstrate the effect of learning rates in the classification accuracy of a CNN. This has been achieved through the performance of the experiments using three learning rates with various class sizes. This work also assesses the accuracy of the original CNN model when different plant species are used with different learning rates. The learning rates that have been used in the experiments are 0.001, 0.0001, and 0.00001, respectively.

A. The Data

This work has used two sets of data. One set comprised of images from the PlantVillage dataset while the other dataset comprised of images from the Nepal database. The algorithm used for this work is routing by agreement with a convolution of 256 filters, a kernel size of 9, and a ReLU activation function [23]. The model has 32 channels and a kernel size of 9 with a vector dimension of 16. It contains a decoder network with 3 dense layers (512; 1024; shape). Images from the PlantVillage database were resized for use in this research. The routing by agreement algorithm has been used by Hinton et al. [22] for lung cancer screening. Mobiny and Van Nguyen [24] used the algorithm to detect movements in movies. In this work, each capsule attempted to predict the output of the parent capsules, and when the prediction conformed to the actual output of the parent capsule, then there it was assumed that there was an increase in the coupling coefficient between the two capsules as outlined by Gogola et al. [25]. This work has also tested the same dataset on a convolutional neural networks (ConvNet) model and the results were recorded.

The general procedure for disease classification involved several stages, such as image acquisition, data pre-processing, and data classification. Thereafter, training and validation of the dataset were performed using different learning rates in the normal CNN model [22] for classifications. The overall workflow diagram for the techniques adopted is presented in Fig. 1.

B. Image Acquisition

This phase involved the acquisition of images from the PV dataset while other images were from the Nepal database. The images were initially collected under different conditions that were either controlled, wild, or uncontrolled before being put under laboratory conditions.

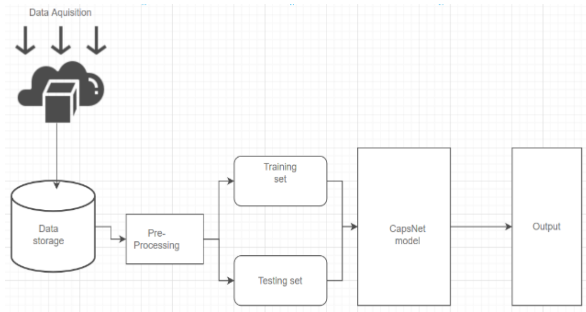

Fig. 1. The General Flow Diagram.

C. Pre-processing

Pre-processing techniques that were used include resizing and checking dimensionality. For this work, each image from the dataset was checked to find out if they were of the same squared shape. The images that were not of the squared shape were cropped to get the center square part of the image for good classification. All images were then resized to 28 x28 pixels. Image resizing was done using Photoshop where the large images were reduced in size and unneeded pixel information was discarded. In cases where the images were too small, Photoshop was used to enlarge, create a pixel and add new pixel information. Resizing was done to reduce the number of parameters and increase the processing speed.

D. Training and Testing Data Sets

In regards to splitting, the entire dataset was divided into two subsets one used to train the model and the other used to test the model. The testing subset was used to make predictions that were compared with the original one to check the model accuracy. The major objective of splitting was to be able to evaluate the model based on new data; data that had not been used to train the model. In all the experiments, the test set was 0.3 of the total number of images while the training set was 0.7 of the total images used.

E. Experimental Results

The first six experiments were done using four disease classes as shown in Table I. The total number of images that were used for this experiment was 10295 and 30% of that was used for testing while 70% was used for training. In the first and second experiments, the learning rate that was used was 0.0001 and the accuracy observed on training was 99.9% while that of testing was 99% in the Capsule neural network (CNN) model. While the ConvNet model displayed 100% on training and 98.75% on testing. The levels of accuracies and losses have been represented by Fig. 2 and Fig. 3 for CNN, 4 and 5 for ConvNet.

TABLE I. THE CLASSES THAT WERE USED FOR THE FIRST, SECOND AND THIRD EXPERIMENTS

Disease	Plant	No.of images
Esca Black Measles	Grape	2573
healthy	Grape	2370
Leaf blight Isariopsis Leaf Spot	Grape	2450
Huanglongbing Citrus greening	Orange	2902

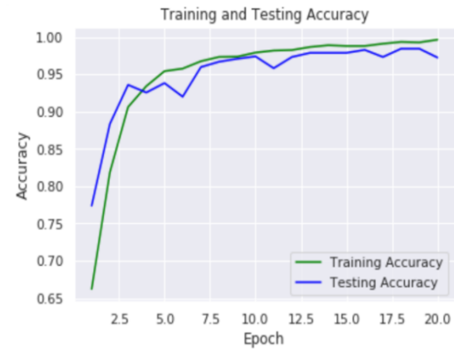

Fig. 2. Training and Testing Accuracy for CNN using Learning Rate of 0.0001 with 4 Disease Classes.

Fig. 3. Training and Testing Loss for CNN using Learning Rate of 0.0001 with 4 Disease Classes.

Fig. 4. Training and Testing Accuracy for ConvNet using Learning rate of 0.0001 with 4 Disease Classes.

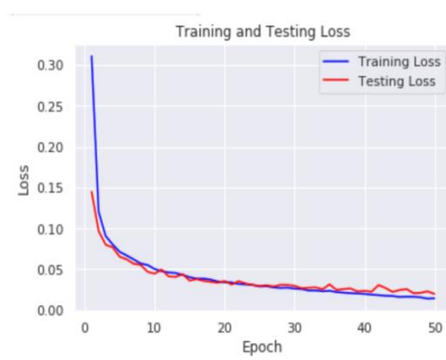

Fig. 5. Training and Testing Loss for ConvNet using Learning Rate of 0.0001 with 4 Disease Classes.

In the third and fourth experiments, the highest accuracy reached on training was 94% while the testing accuracy was 97.0% for the capsule neural network (CNN) while the Convolutional neural network (ConvNet) had 97% accuracy on testing and 99% accuracy on training. The learning rate for this particular experiment was 0.00001. Fig. 6 and 7 show the graphs for training and testing accuracy and loss for CNN while Fig. 8 and 9 show training and testing accuracy and loss for ConvNet.

Fig. 6. Training and Testing Accuracy for CNN using Learning Rate of 0.00001 with 4 Disease Classes.

Fig. 7. Training and Testing Loss for CNN using Learning Rate of 0.00001 with 4 Disease Classes.

Fig. 8. Training and Testing Accuracy for ConvNet using Learning rate of 0.00001 with 4 Disease Classes.

Fig. 9. Training and Testing Loss for ConvNet using Learning rate of 0.00001 with 4 Disease Classes.

The fifth and sixth experiment was performed using 10295, and 30% of that was used for testing. The highest accuracy reached on training was 99.9% while the testing accuracy was 81% for Capsule neural network (CNN). The testing accuracy for convolutional neural network (ConvNet) was 96.5 while that of training was 99.0%. The learning rate for this particular experiment was 0.001. Fig. 10 shows the graph for training and testing accuracy for CNN, while Fig. 11 shows training and testing loss for CNN. Fig. 12 and 13 show training and testing accuracy and loss for ConvNet, respectively.

Fig. 10. Training and Testing Accuracy for CNN using Learning Rate of 0.001 with 4 Disease Classes.

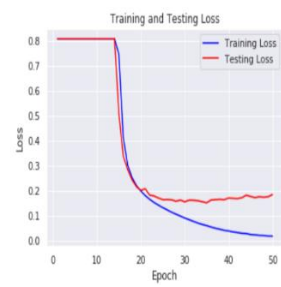

Fig. 11. Training and Testing Loss for CNN using Learning Rate of 0.001 with 4 Disease Classes.

Fig. 12. Training and Testing Accuracy for ConvNet using Learning Rate of 0.001 with 4 Disease Classes.

Fig. 13. Training and Testing Loss for ConvNet using Learning Rate of 0.001 with 4 Disease Classes.

The next experiments were done using six classes as shown in Table II. The total number of images that were used for this experiment was 12265 and 30% of that was used for testing. The learning rates that were used for the experiments were 0.0001, 0.00001, and 0.001, respectively. In the seventh and eighth experiments, the accuracy observed on training was 99.9% while that of testing was 99% for Capsule neural network (CNN) while the training and testing accuracy for the convolutional neural network (ConvNet) was 100% and 96.2%, respectively. The levels of accuracy and loss for CNN have been represented in Fig. 14 and Fig. 15, respectively while those of ConvNet have been represented in Fig. 16 and 17.

TABLE II. THE CLASSES THAT WERE USED FOR THE FOURTH, FIFTH AND SIXTH EXPERIMENTS

Disease	Plant	No.of images
Esca Black Measles	Grape	2573
healthy	Grape	2370
Leaf blight Isariopsis Leaf Spot	Grape	2450
Huanglongbing Citrus greening Early_blight Healthy	Orange Tomato Tomato	2902 1000 970

Fig. 14. Training and Testing Accuracy for CNN using Learning Rate of 0.0001 with 6 Disease Classes.

Fig. 15. Training and Testing Loss for CNN using Learning Rate of 0.0001 with 6 Disease Classes.

Fig. 16. Training and Testing Accuracy for ConvNet using Learning rate of 0.0001 with 6 Disease Classes.

Fig. 17. Training and Testing Loss for ConvNet using Learning Rate of 0.0001 with 6 Disease Classes.

In the ninth and tenth experiments, the learning rate used was 0.001 and the highest accuracy reached on training was 99.1% while the testing accuracy was 97.5% while using Convolutional Neural network (ConvNet). Training and testing accuracies were 100% and 98% for Capsule Neural Network (CNN) respectively. Fig. 18 shows the graph for training and testing accuracy, while Fig. 19 shows training and testing loss for ConvNet. Fig. 20 and 21 show training and testing accuracies for CNN.

Fig. 18. Training and Testing Accuracy for ConvNet using Learning Rate of 0.001 with 6 Disease Classes.

Fig. 19. Training and Testing Loss for ConvNet using Learning Rate of 0.001 with 6 Disease Classes.

Fig. 20. Training and Testing Accuracy for CNN using Learning Rate of 0.001 with 6 Disease Classes.

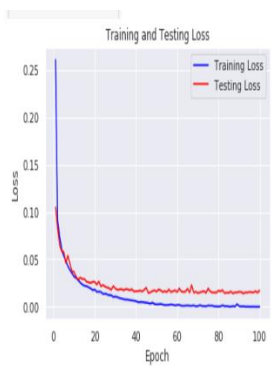

Fig. 21. Training and Testing Loss for CNN using Learning Rate of 0.001 with 6 Disease Classes.

In the eleventh and twelfth experiment, the learning rate was 0.0001 and the highest accuracy reached on training was 100% while the testing accuracy was 98.84% for Capsule Neural Network (CNN) while training and testing accuracies for Convolutional Neural Network (ConvNet) were 99.9% and 80%, respectively. Fig. 22 shows the graph for training and testing accuracy while Fig. 23 shows training and testing loss for ConvNet while Fig. 24 and 25 shows training and testing accuracies and losses for CNN.

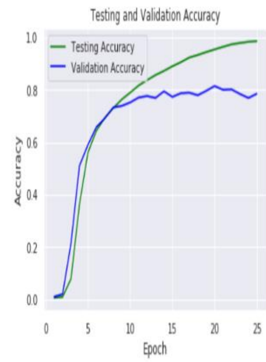

Fig. 22. Training and Testing Accuracy for ConvNet using Learning Rate of 0.0001 with 8 Disease Classes.

Fig. 23. Training and Testing Loss for ConvNet using Learning Rate of 0.0001 with 8 Disease Classes.

Fig. 24. Training and testing accuracy for CNN using learning rate of 0.0001 with 8 disease classes

Fig. 25. Training and Testing Loss for CNN using Learning Rate of 0.0001 with 8 Disease Classes.

The next experiments were done using 10 classes as shown in Table III below. The total number of images that were used for this experiment was 12751 and 30% of that was used for testing. The learning rate that was used for the thirteenth and fourteenth experiment was 0.0001 and the accuracy observed on training was 99.9% while that of testing was 93% for Capsule Neural Network (CNN). The level of accuracy and loss for training and testing using Convolutional Neural network (ConvNet) was 100% and 97.5%, respectively. The levels of accuracies and losses for CNN have been represented by Fig. 26 and Fig. 27 below while those of ConvNet have been represented by Fig. 28 and 29, respectively.

TABLE III. THE CLASSES THAT WERE USED FOR THE SEVENTH, EIGHTH AND NINTH EXPERIMENTS

Disease	Plant	No.of images
Healthy	Coffee	145
Miner	Coffee	400
Rust	Coffee	943
phoma	Coffee	1000
Cercospora	Coffee	870
Common_rust	Corn	2000
Healthy	Corn	1270
Cercospora_leaf_spot	Corn	1870
Gray_leaf_spot	Blueberry	2276
Healthy	Cherry	1977

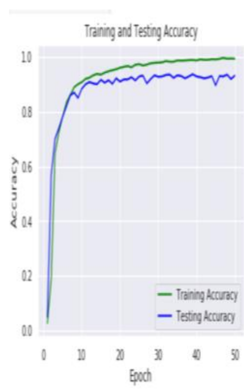

Fig. 26. Training and Testing Accuracy for CNN using Learning Rate of 0.0001 with 10 Disease Classes.

Fig. 27. Training and Testing Loss for CNN using Learning Rate of 0.0001 with 10 Disease Classes.

Fig. 28. Training and Testing Accuracy for ConvNet using Learning Rate of 0.0001 with 10 Disease Classes.

Fig. 29. Training and Testing loss for ConvNet using Learning Rate of 0.0001 with 10 Disease Classes.

In the fifteenth and sixteenth experiments, the highest accuracy reached on training was 91% while the testing accuracy was 91% for Capsule Neural Network (CNN), while Convolutional Neural Network (ConvNet) showed 97.75% for testing and 100% for training. The learning rate (LR) for this particular experiment was 0.00001. Fig. 30 and 31 show the graphs for training and testing accuracy and loss using CNN. Fig. 32 and 33 shows training and testing accuracy and loss observed from ConvNet.

In the seventeenth and eighteenth experiments, the highest accuracy reached on training was 99.9% while the testing accuracy was 81% while using Capsule Neural Network (CNN). On using Convolutional Neural Network (ConvNet) the testing accuracy was 97.75% while that of training was 100%. The learning rate for this particular experiment was 0.001. Fig. 34 shows the graph for training and testing accuracy while Fig. 35 shows training and testing loss for CNN while Fig. 36 and 37 show training and testing accuracies and losses for ConvNet.

Fig. 30. Training and Testing Accuracy for CNN using Learning Rate of 0.00001 with 10 Disease Classes.

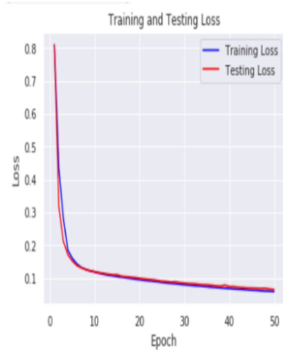

Fig. 31. Training and Testing Loss for CNN using Learning Rate of 0.00001 with 10 Disease Classes.

Fig. 32. Training and Testing Accuracy for ConvNet using Learning Rate of 0.00001 with 10 Disease Classes.

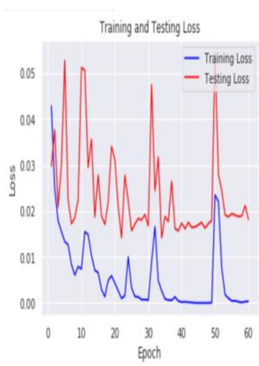

Fig. 33. Training and Testing Loss for ConvNet using Learning Rate of 0.00001 with 10 Disease Classes.

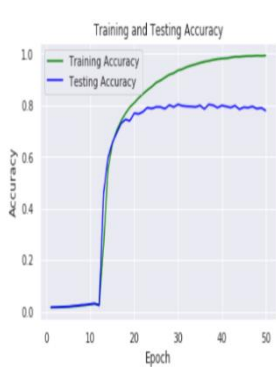

Fig. 34. Training and Testing Accuracy for CNN using Learning Rate of 0.001 with 10 Disease Classes.

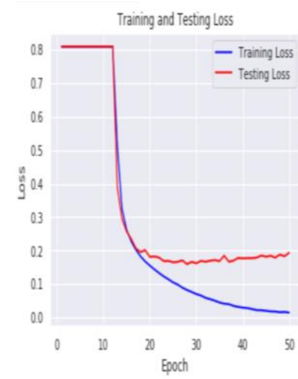

Fig. 35. Training and Testing Loss for CNN using Learning Rate of 0.001 with 10 Disease Classes.

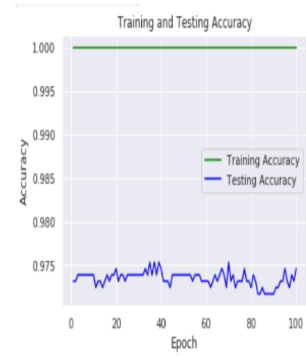

Fig. 36. Training and Testing Accuracy for ConvNet using Learning Rate of 0.001 with 10 Disease Classes.

Fig. 37. Training and Testing Loss for ConvNet using Learning Rate of 0.001 with 10 Disease Classes.

A total of 21121 images and 30% of that were used for testing for the next experiments. Table IV shows the classes that were used for the experiments. In the nineteenth and twentieth experiments, the highest accuracy reached on training was 99.9% while the testing accuracy was 97.4% while using Capsule Neural Network (CNN). On using Convolutional Neural Network (ConvNet) testing accuracy observed was 98.04% while that of testing was 100%. The learning rate (LR) for this particular experiment was 0.0001. Fig. 38 shows the graph for training and testing accuracy while Fig. 39 shows training and testing loss for CNN. Fig. 40 and 41 show training and testing accuracies and losses for ConNet.

TABLE IV. THE CLASSES THAT WERE USED FOR THE TENTH, ELEVENTH AND TWELFTH EXPERIMENTS

Disease	Plant	Number of images
Healthy	Coffee	145
Miner	Coffee	400
Rust	Coffee	943
phoma Cercospora Common_rust Healthy Cercospora_leaf_spot Gray_leaf_spot Healthy Healthy Black_rot Esca_(Black_Measles) Healthy Leaf_blight_(Isariopsis_Leaf_Spot) Haunglongbing_(Citrus_greening) Healthy	Coffee Coffee Corn Corn Corn Blueberry Cherry Grape Grape Grape Grape Orange Soybean	1000 870 2000 1270 1870 2276 1977 1000 2573 2370 977 800 650

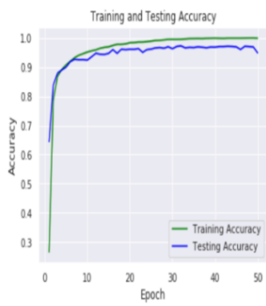

Fig. 38. Training and Testing Accuracy for CNN using Learning Rate of 0.0001 with 16 Disease Classes.

Fig. 39. Training and Testing Loss for CNN using Learning Rate of 0.0001 with 16 Disease Classes.

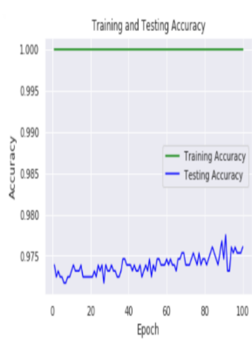

Fig. 40. Training and Testing Accuracy for ConvNet using Learning Rate of 0.0001 with 16 Disease Classes.

Fig. 41. Training and Testing Loss for ConvNet using Learning Rate of 0.0001 with 16 Disease Classes.

In 21st and 22nd experiments, the highest accuracy reached on training was 100% while the testing accuracy was 97.3% for Capsule Neural Network (CNN). The training and testing accuracies for Convolutional Neural Network (ConvNet) were 100% and 98.04%, respectively. The learning rate for this particular experiment was 0.00001. Fig. 42 shows the graph for training and testing accuracy while Fig. 43 shows training and testing loss for CNN while Fig. 44 and 45 show training and testing accuracies and losses for ConvNet.

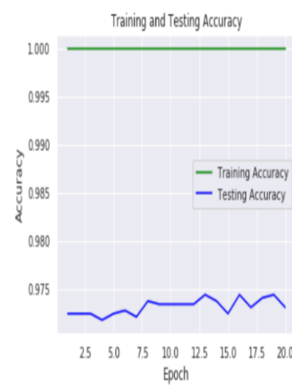

Fig. 42. Training and Testing Accuracy for CNN using Learning Rate of 0.00001 with 16 Disease Classes.

Fig. 43. Training and Testing loss using Learning Rate of 0.00001 with 16 Disease Classes.

Fig. 44. Training and Testing Accuracy for ConvNet using Learning Rate of 0.00001 with 16 Disease Classes.

Fig. 45. Training and Testing Loss for ConvNet using Learning Rate of 0.00001 with 16 Disease Classes.

The total number of images that were used for the 23rd and 24th experiment was 15220 and 30% of that was used for testing. The highest accuracy reached on training was 99.9% while the testing accuracy was 84.5% for Capsule Neural Networks (CNN). The testing accuracy reached for Convolutional Neural Network (ConvNet) was 98.40% while that of training was 100%. The learning rate for this particular experiment was 0.001. Fig. 46 shows the graph for training and testing accuracy while Fig. 47 shows training and testing loss. Fig. 48 and 49 show training and testing accuracies and losses for ConvNet.

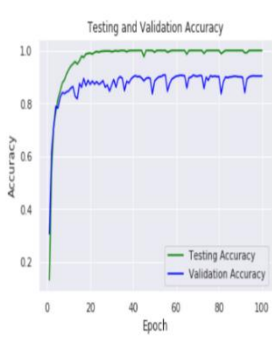

Fig. 46. Training and Testing Accuracy for CNN using Learning Rate of 0.001 with 16 Disease Classes.

Fig. 47. Training and Testing Loss for CNN using Learning Rate of 0.001 with 16 Disease Classes.

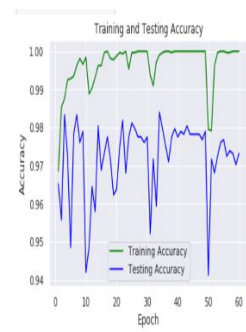

Fig. 48. Training and Testing Accuracy for ConvNet using Learning Rate of 0.001 with 16 Disease Classes.

Fig. 49. Training and Testing Loss for ConvNet using Learning Rate of 0.001 with 16 Disease Classes.

From Table V, the highest accuracy of 0.99 was observed on recognition when the learning rate of 0.0001. On the other hand, the lowest accuracy of 0.81 was observed on recognition when the learning rate was 0.001. It was also noted that when images from other databases were added to those from PlantVillage, accuracy dropped from 0.99 to 0.97; hence it was concluded that CNN works best with PlantVillage datasets when it comes to disease detection. The best accuracy in testing while using ConvNet was 98.8%. It was however noted that there was a loss of data due to pooling which may have led to lower accuracies in both testing and training. There was also overfitting which shows that ConvNets are affected by dataset size, unlike the CNN which was not affected by dataset size at all. It was also noted that when images from other databases were added to those from PlantVillage, accuracy dropped from 0.99 to 0.97; hence it was concluded that CNN works best with PlantVillage datasets when it comes to disease detection.

TABLE V. RESULTS ANALYSIS FOR BOTH TRAINING AND TESTING IN CNN AND CONVNET

Dataset Size	Learning Rate	Convolutional Neural Network(ConvNet)		Capsule Neural Network(CNN)	
		Training accuracy (%)	Testing accuracy (%)	Training accuracy (%)	Testing accuracy (%)
10295	0.001	99	96.5	99	81
	0.0001	100	98	99.9	99
	0.00001	99	96.5	94	97.0
12265	0.001	99.9	80	100	98.84
	0.0001	100	96.2	99.9	99
	0.00001	99.1	97.5	100	98
12751	0.001	100	97.75	99	81
	0.0001	100	97.5	99	93
	0.00001	100	97.8	91	91
21121	0.001	100	98.4	99.9	84.5
	0.0001	100	98.0	99	97.4
	0.00001	100	98.04	99.9	97.3

The values chosen for learning rates can speed up the training processes of neural networks [40]. The author in [42] studied the effect of fine-tuning the learning rate together with the batch size and proposed the adjustment of learning rates relative to the batch size. This work used large and small batch size datasets of 21121and 10295 plant images. The author in [44] characterized the functions of learning rates on training and testing accuracies of neural network models. With this is the critical hyperparameter of the gradient descent learning rate [45]. Neural networks, according to several studies, do not learn when very large learning rates are used [46, 47, 48, and 49]. These studies further state that the use of very small learning rates leads to slow optimization and poor accuracy results. This study found that the model was able to learn with learning rates of 0.00001, 0.0001, and 0.001. However, the learning time for the 0.0001 learning was slower compared to the 0.001 learning rate. In support of this, [50] notes that very high learning rates need constant training that may end up consuming more time than is necessary and fail to achieve the expected accuracy. On the other hand, very low learning rates result in gradient decline, as well as lead to an increase in the number of reiterations [52].

From Table V, it was also observed that the training rate was relatively low when the learning rate was at 0.00001 while the training rate was high when the learning rate was either 0.001 or 0.0001. To strike a balance, the learning rate of 0.0001 for both training and testing was able to give a perfect fit.

VII. DISCUSSION

This section was used to examine the importance and performance of learning rates in neural networks' training for optimum test accuracies. Studies such as [40, 41, 42, 43], have recognized the influence of learning rates in achieving high accuracies. Neural networks' training processes are usually affected by learning rates. When the training is done many times, the learning rate can be affected and the system may fail to generate high accuracies as expected. The author in [40] established the triangle cyclic learning rates that included TRI2, TRI, and TRIEXP. However, this method does not require the use of specific learning rates but periodically varies the learning rate at certain intervals. Our study on the other hand used specific learning rates of 0.00001, 0.0001 and 0.001.

The findings by [11] match our results regarding the relationship between learning rates and dataset sizes. The author in [11] proposed the use of smaller dataset sizes. However, our results do not agree with [12], who note that the use of larger learning rates, results in an increased accuracy result for the neural network. This is because from our results smaller learning rate of 0.0001 had the highest accuracies ranging between 93.7% and 99%, unlike the larger learning rate of 0.001 that had learning rates ranging from 80% and 84.5%. Similarly, [51] performed simulations where learning rates of 0.001 and 0.01 resulted in the best accuracy percentages. Smaller learning rates produced higher accuracy values and more time taken for the test training. Conversely, larger learning rates result in reduced accuracy percentages and a fast training process. Concerning larger dataset size, our findings agree with [12] that the higher the size, the better the neural performance. This work proposes the use of large dataset sizes. This is supported by [12] on the relationship between learning rates and batch sizes. This work highlights that larger dataset sizes require higher learning rates. The reason being that a larger dataset size of 21121 had the highest accuracy of 84.5% for the larger learning rate of 0.001. The author in [10] recommends a default batch size value of 32. The author in [53] was able to achieve the highest accuracy values using a batch size of 16. Other studies used ten classes of image datasets to achieve the best performance [54, 55, and 56]. This work used the batch size of 10 and CNN algorithm and the best performance (99% and 97.4%) was achieved for a dataset of 12,265 and 9899 images (11 classes and 4 classes, respectively) using the smaller learning rate of 0.0001. Larger learning rates have also been used by [58], who used a learning rate of 0.4 and achieved a 75% accuracy. The author in [58] used two learning rates of 0001 and 0.01 to achieve the best performances and observed that the lower learning rate gave a higher accuracy as compared to its higher counterpart. These learning rate values have been supported by [59] whose study also produced the highest accuracy from the use of correct input parameters. The study concludes that CNN works best with a learning rate of 0.0001 when all other things are kept constant. Another observation according to this work was that other databases do not work well with CNN just like the PalntVillage datasets [57]. The introduction of coffee from a different database lowered the accuracy levels from 99% to 97%.

VIII. Conclusion

In conclusion, this work was able to observe that a large learning rate tended to move in the “correct” direction, which led to overshooting or surface error that could have interfered with the accuracy hence made the training process consume more time. This could be because of the constant “unlearning” and overshooting problems that require backtracking. Under normal circumstances, the failure to backtrack can result in failed fluctuations and poor accuracy percentages [20]. In this work, it was observed that small learning rates prevented instabilities and overcorrections, and allowed for a smooth path over the error landscape to reach a minimum. A lower learning rate further resulted in a smoother path and therefore, to significantly improve the testing accuracy, one can reduce the learning rate.

From research done by [9], there are no predefined learning rates but should be between 0 and 1.0 so there is a need to balance and there is no better way to do that other than to test several learning rates and observe their performances. This work adopts the use of online training instead of batch training. This is because batch training needs more time compared to online training with no corresponding improvement inaccuracy [5].

Nonetheless, there is a limit to the times one can decrease the learning rate. To avoid wasting time at such points, one should avoid repeating the same steps while taking the same path that results in the same minimum. Learning rate affects the testing and training accuracies of CNN and therefore researchers have to explore different learning rates before settling on one. When the learning rate was high at 0.001, the recognition rate was low at 84% and the model experienced a lot of losses. But when the learning rate was relatively low at 0.0001, recognition rates were high at 99% and minimal loss was observed. For CNN, to show good results, at both training and recognition, this work suggests the use of a 0.0001 learning rate. There is a need to further investigate the effect of batch sizes on test accuracies using adjusted learning rates ranging between 0 and 1.

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A Systematic Review Web Content Mining Tools and its Applications

Systematic Review Web Content Mining Tools

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***Abstract*—In recent years, the emergence of WWW (World Wide Web) led to the accumulation of huge amount of information and data. Hence the web is found to consist of unstructured and structured information that impacts the day to day life of the society. Because of such availability of huge information, utilization of the required information becomes more challenging. This paper provided a comprehensive survey on the current situation and recent trends on web content mining (WCM) and its applications thereby contributing to the enhancement of the upcoming research in WCM. The paper focused mainly on the mining and retrieval techniques, various WCM approaches, challenges and process of information retrieval and information extraction. The paper describes the four major tasks of web content mining that is information retrieval, information extraction, generalization and validation in detail. WCM concentrates on orchestrating, sorting, classifying, collecting, congregating of web data and provide the improved data which can be easily accessed by the users. Web content mining tools were needed to scan text, images and HTML documents and provide results to the search engine. It guides the search engine to provide better productive results for every search based on their importance. The paper also analysed different web content mining tools for the extraction of relevant information from the corresponding web page.**

***Keywords*—Web content mining; web structure mining; web usage mining; data mining; information retrieval; information extraction**

I. Introduction

There exist several under-research fields, such as relevance ranking of webpage, knowledge in web documents, etc. in the Web Content Mining. The extraction of useful patterns and information from the page content, web hyperlink structure and usage data with the employment of data mining and artificial intelligence methods is termed as web content mining. Few techniques such as association rule mining, classification analysis, support vector machine, clustering analysis are utilized for the purpose. The main contribution of the review is to frame a semi structured and comprehensive overview of the problems, methods and solutions of the prevailing web content extraction problems [1].

Enormous growth of data leads to numerous creation of web pages for analyzing and mining of useful data but it is practically challengeable. WWW includes billions of millions of interlinked web pages created by billions of millions of authors on the world. Web page is kind of document utilized to view WWW with use of web browser [2]. Massive source of data in form of unstructured and structured data is added to the web daily, which makes data extraction complex. Technique for efficient data mining from the web is imperatively prominent requirement for the user. Data mining is widely utilized technique in government security, science explores and business [3, 4]. Web mining is an application of data mining method which is semi-structured or unstructured data, automatically find and extract most useful, unknown information from the web [5]. Few applications of web mining is: web communities, web market places, artificial intelligence, business, e-commerce, network management, information retrieval, search engines, web search and web design. Process of web mining consist of 4 steps such as: finding of resources, selection of data, pre-processing generalization and examination of resource findings. Resource finding is process utilized to mine data either from offline or online resources. In selection of data and pre-processing step, information which is retrieved from web resources is selected and pre-processed automatically. During generalization step, machine learning and data mining methods were utilized to find common patterns from every websites. In analysis step, extracted data undergoes validation and interpretation.

This study includes six sections such as: Section 1 gives introduction to data and web mining. Section 2 explores categories of web mining. Section 3 and Section 4 elaborates tools and techniques related to content mining. Section 5 gives comparison of web content mining tools and Section 6 concludes this survey with future work.

II. Categories of Web Mining

Web mining is categorized into three major types (3):

- WSM (Web Structure Mining).
- WUM (Web Usage Mining).
- WCM (Web Content Mining).

A. WSM

WSM is a study of data related to structure of specific website [6]. It includes web graph which consist of web reports or web pages as nodes and hyperlink are consider as edges which links two connected pages. WSM is process of mining web graph patterns such as complete graph, social choice, co-citation, etc. Sited page is ranked by varied points and web page is selected in order to include within page group. This kind of mining is performed at page level or in-between page level [5]. This mining determines the structure knowledge from the web link structure. Concentrating on web link structure is big challenge for this kind of mining. The main use of this mining is to examine the web pages and arrange in structurally manner, Fig. 1.

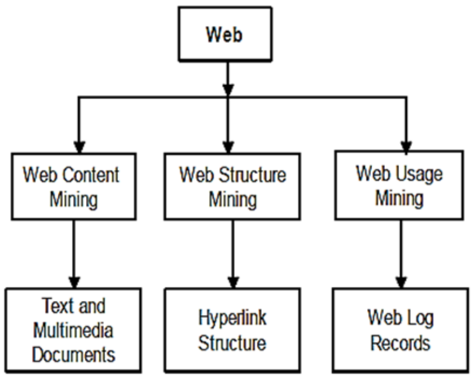

Fig. 1. Classification of Web Mining [7].

B. *WUM*

WUM also called as web log mining mainly utilized to examine users behavior on web. This mining concentrates on methods which predicts user knowledge when they are in online. Primarily it concentrates to track behavior of the user based on their personalized and generalized web usage [8]. According to generalized tracking extraction of knowledge is done related to user's web page history. Whereas in personalized tracking, extraction of knowledge is done from web interaction of users. Sources of this mining are logs of proxy server, server logs, bowser logs, and client logs. Main purpose of this mining is data pre-processing which includes data identification, cleaning and developing user sessions, extracting information of particular web page and formatting that particular data. Once pre-processing of data gets completed then data mining algorithm is used to detect behavior of the user.

C. *WCM*

It is a process of mining necessary and beneficial data from the web pages. It's mostly linked with text mining since most of the web content consist of text. It also concentrates on content of web page like images, text and some other media files which are attached. Here pre-processing is carried out on content of web page. WCM is utilized in various web applications with intension to identify web objects which have common patterns or characteristics [9, 10]. It is naturally semi-structure format of web. It has two kids: one type directly extracts document's content and another type enhance search of content with tools like search engine. WCM is utilized to analyze collected data with help of web spider and search engine. Generally utilized technology in this technique are NLP (Natural Language Processing) and IR (Information Retrieval). Two methodologies utilized in ECM are agent-based and database approach. Where Database method will retrieve semi-structured data from the web document. Agent-based method use three types of agents such as: intelligent search agent, information filtering classifying agent, customized web agent. Where customized web agent tries to determine web page on user profile. Information filtering classifying agent minimize effort and time of users in finding relevant document. Intelligent search agent automatically finds information related to the query of users. Various categories of WCM is discussed in below section.

III. Various Techniques of WCM

WCM were used to extract information from web pages [5]. Various techniques of WCM is illustrated in Fig. 2.

- Unstructured Content mining.
- Structure data mining.
- Semi-Organized data mining.
- Multimedia data mining.

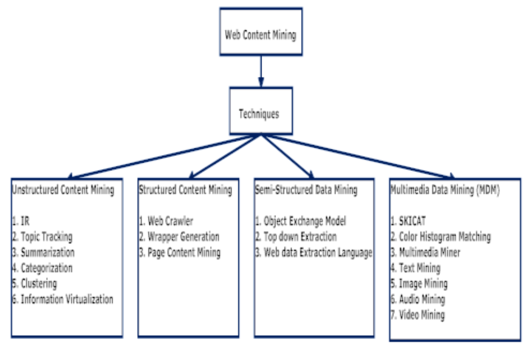

Fig. 2. Techniques of Web Content Mining [13].

A. *Unstructured Content Mining.*

Mostly web content will be unstructured data format. Using data mining methods with unstructured data is referred as KDT (Knowledge Discovery in Text) [10]. Hence text mining is consider as instance of web content mining. For effective result, pre-processing step must be carried out with help of NP, IR or text categorization techniques [11].

1) Units: Information can be mined from unstructured data with use of pattern co-ordination. IR tracks the expressions and keywords and also finds association of keywords within the content [12]. This method is suitable for large size text. IR is basic for all technologies which is utilized in un-organizing mining and also finds KDD, because IR converts unorganized data into more organized data structure. Primarily, data is mined from the mined data then various kinds of rules were utilized to find the lost information.

2) Topic tracking: This technology analyzes the document based on user view and predicts the document based on their interest. It is a process determining web document related to query of the user by finding the web pages which is related to user topics and also use hyperlinks to find set of web pages which is related to user topic.

3) Summarization: It is utilized to minimize document length by controlling the main points. It supports the users for taking decision whether it can be read or not. Time taken for summarization of document is minimum when compared to time taken to read the 1st paragraph by the users. One of the risk with summarization was to teach the software to examine semantics and to understand the meaning. This software statistically balances the sentence and mine the needed sentence from documents. Summarization tool is used to understand key point of the documents. This tool provides freedom to user to choose the percentage of text to be mined as summary. It also work with categorization and topic tracking to summarize the document. Microsoft auto summarize word are example of summarization.

4) Categorization: This technique position the document in pre-defined set of set. It counts total number of words within document based on this main topic is decided. Rank is awarded to document based on the topic. Document which gives major preference to particular topic are considered first. This technique supports business and industries. Categorization is divided into two types.

5) Web page categorization: It is process of allocating category or class to web page from group of prior categories or classes [14]. This categorization differs from conventional document categorization process by the features like, primarily traditional text document which is employed on consistent style and structure format where web page won't have attribute. Secondly, generally web page exist in unstructured HTML format and has attributes like description, head, tittle and keyword [15].

6) Web site categorization: Various techniques were used to classify web site. One of the technique is web site home page content dependent classification and another technique is HTML tag utilized to categories websites as performed in 16 and another technique utilize link structure attribute dependent classification. Website classification is also supported by webpage classification 18.

7) Clustering: This technique is utilized to cluster similar documents. Here grouping was performed depending on fly not on predefined topics. Same document appears in various group. Because of this, useful document won't be deleted from search the result. This technique supports the user in easy selection of topic of user interest. This technique is utilized in MIS (Management Information Systems). Clustering can be done in different ways such as:

a) Web page Clustering: This technique group's webpages based on related content, this is useful for IR approaches and search engines, which enhance accessibility and create content depending on delivery applications.

b) Web Object Clustering: IT groups objects such as sound tracks, video, audio, images and text according to the user queries.

c) Web Site Clustering: This technique groups similar websites which have similar characteristics. There are numerous challenges with implementation such as: mining textual content from various webpages is tedious process and needs several pre-processing steps, and then extraction of multimedia content like video, audio and image requires new technique which is complex to implement.

8) Information virtualization: Web content can be compressed with use of virtualization tools. So there is need to enhance tool in a way to provide graphical representation of web objects. These tools visualize information, like user access pattern, webpage correlation, website relationship, users click stream and web usage time, etc. There are numerous visualization tools like T-SNE, Ggobi, NCSS, STATISTICA, these tools provide the content in form of scatter plots, histogram, etc.

B. Structured Content Mining

This type of mining is simpler compared to unstructured data mining. In webpage, host page are called as structured data. This process have three techniques, such as: page content mining, web crawler and web generation. Process of mining structured data is referred as wrapper. Data retrieved from the database with use of pre-defined structure in webpage called as structured data [16]. This technique supports user to organize data from various sources [11].

1) Web crawler: It's also called as web spider is an intelligent software program used to search over the web for particular information. Search engine with support of web crawler provide fast search result. This is performed by duplication browsed data from webpages for future action and the downloaded pages are indexed [17]. It also automatically update the indexes and web content. For extraction of information, web crawlers utilize techniques such as soft computing techniques, PSO, genetic algorithm and breath-first search. And also traverse through hyperlink to mine knowledge.

2) Wrapper generation: Wrappers serves Meta information like statistics, index links, and source domain. In this technique, depending on source capacity information is provided. Wrapper mine content from particular source of data to convert it to link structured manner [18]. There are two ways to perform wrapper generation they are: automatic and induction data extraction. For induction type, supervised learning is utilized to extract information from trained program given by users. Automatic data extraction is all ways possible since most of the web data is in generic form.

3) Page content mining: This process categorizes web pages. This techniques functions based on page ranking provided by standard search engines.

4) Semi-Structured data mining: It is not grammatical or full text. Semi-structure data won't have pre-define structure, it will be in hierarchical in nature. There are various methods to mine semi structure data like NP, ontology, wrapper generation. To mine such kind of data there is need for general technique to develop particular grammar in a way of briefing to extract surrounding piece of data.

5) Object Exchange Model (OEM): Relevant data is mined from semi-structure and is grouped in form of useful information and preserved in OEM. This supports user for easy and clear understanding of information structure which exist in web. This model is self-describing so there is no necessary for description of object structure in advance [7].

6) Top down extraction: This method supports to mine difficult items from off-sources of web and break those difficult items to less complicate items. This process continues till atomic elements were separated.

7) Web data extraction language: This technique converts to structured data from web data which was given to end-users. This technique stores data in table format.

C. Multimedia Data Mining (MDM)

It is a process of determining patterns from media data like image, text, audio and video which are not accessible with use of queries [7]. MDM involves with standard statistics, association rule, sequence pattern mining, clustering and classification. Intention of MDM is to find indices construction, multimedia data, retrieval implementation and description dependent retrieval with use of size, time stamp, caption, tags and keywords, and content dependent retrieval with use of wavelet transform, shape, texture, histogram, color. MDM involves in two steps like: mining features from data and choosing multimedia mining techniques to find preferred contents. MDM is categorized as follows [19]:

1) SKICAT: It is astronomical cataloging and data analysis system which develop digital catalog of sky objects. It utilizes machine learning methods to translate object into human classes. It combines methods for data classification and image processing which supports to categorize huge classification sets.

2) Color histogram matching: This technique comprise of smoothing and shading histogram equations. Equation tries to find relationship among parts of color. Equalization is challengeable task due to existence of unwanted shortages in adjusted pictures. Smoothing is used to resolve this issue [7].

3) Multimedia miner: It consist of 4 steps they are: In step 1, image excavator for mining videos and images. In step 2, preprocessor for mining image features and preserved in database. In step 3, search kernel is utilized for matching queries with videos and images which exist in database. In step 4, discovery modules extract image information to trace patterns in image.

4) Text mining: It is process of using data mining methods to mine text portions from unstructured web documents. BOW (Bag of Words) is general model utilized in web mining to indicate presence or absence of textual features. BOW is also referred as VSM (Vector Space Model) [20].

5) Image mining: It is a process of finding image pattern from huge collection of images. It concentrates on image processing to mine desired features like color histogram, smoothing, line detection, texture analysis to solve analysis of image.

6) Audio mining: It is a process of examining and searching over audio content, particularly utilized with speech recognition [19].

7) Video mining: It is a process of digital video processing which involves in classification of visual objects, content-dependent retrieval, indexing and automatic segmentation [10].

This method is utilized to process video content and also predicts transitions among two frames like former analysis multimedia content.

IV. Various Approaches of WCM

WCM is process of mining needed knowledge from web document. The content may be video, audio, image and text. In WCM issues are related to IR and visualization of database against applications, techniques and data representations. Extraction of information from image is not rapid with web content mining.

WCM performs any one of following approaches:

- Serial WCM.
- Parallel WCM.

A. Serial Approach

Fig. 3 illustrates design of serial WCM. The processing node would process on link dispatched by URL dispatcher. It was noticed that processing and dispatch time remains constant. For instance consider single link, with B(t) as dispatch time and Q(t) as processing time.

For n link, total time V = n * (B(t) + Q(t)) = n * p = W(n), where p denotes positive constant.

B. Parallel Approach

Fig. 4 illustrates design of parallel WCM. Fig. 5 represents various interconnection network to process nodes, they are hypercube, mesh, star, linear array. Due to topology overhead and communication cost, hypercube interconnection network were chosen as best for processing nodes.

K-cube or K-dimension hypercube is generally used interconnection network in parallel processing and broadly used one. It consist of 2k nodes. 2 nodes were consider as neighbor if their address varies in single bit. K-cube have small diameter which is equal to k. In every step, every node communicate with neighbor node for receiving and passing message which needs log n step to broadcast own message to other nodes.

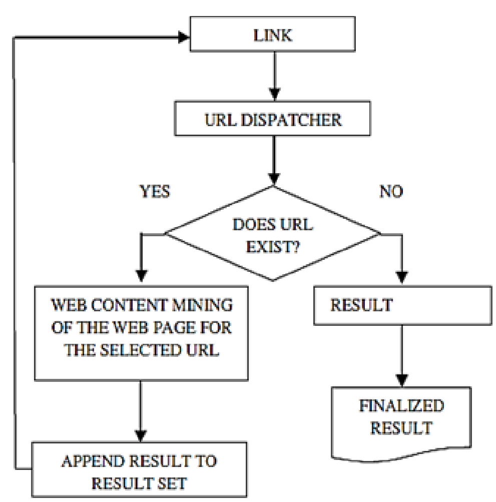

Fig. 3. Serial Approach [21].

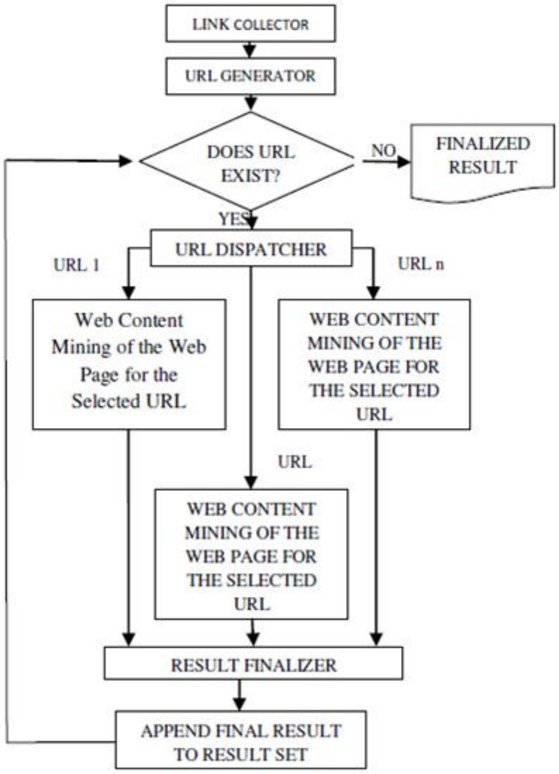

Fig. 4. Parallel Approach [21].

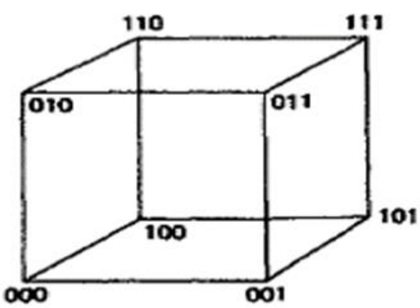

Fig. 5. Representation of Hypercube [21].

V. Various Tools of WCM

In this study, few tools of WCM are considered as most important and reviewed they are:

A. Web Info Extractor

This tool is utilized to mine web data and to retrieve content from web. It retrieve structured or unstructured data from the web page. It doesn't needs complex template rules, where user can browse the webpage and run it [22].

B. Screen-Scraper

It gives (GI) graphical interface facilitating to label URL, data elements to be mined and scripting logic to transverse page and function with mined data. After creating all these items from external language like active server page, PHP, Java, NET, Screen-Scraper could be invoked. This allows scraping of data at regular intervals [22].

C. Mozenda

This tool allow user to mine and control web data. Users set up agents who routinely mine, preserve and publish data to numerous destinations. User can mash-up, recreate and format this tool as per their needs [5].

D. Web Content Extractor

This tool permits users to mine information from several websites like trade directories, economic sites, shopping sites, online public sales and online supplies, etc. Gathered information can transferred to different formats.

E. Automation Anywhere

It is a tool utilized to retrieve web data. Similarly Intelligent automation is a software utilized for information technology and business oriented task.

F. SCRAPY

It is best tool utilized by data professional for learning. It is open source and free software which is written in python language to mine data from websites. It supports information processing and data mining applications to extract structures and crawling of data [23].

G. WEKA

Is a set of machine learning algorithm which consists of clustering, classification, data pre-processing and association rule for data mining applications. The above said algorithm can be used directly with data set. WEKA (Workbench) consist of collation of various tools for visualization and consist of algorithm for data analysis and predictive modelling with GUI (Graphical User Interface) for simple access to their functionality [24, 25].

H. Rapid Miner

It is software environment utilized by same company which provides a combined platform for text mining, data mining and machine learning for business analytics. It is utilized for industrial, application development, rapid prototyping, education training, research, commercial applications and also supports all process in data mining. It utilize client/server module with service provided as cloud infrastructure.

I. ORANGE

It is a machine learning and component dependent data mining software suite, featuring visual programming front-end for explorative visualization and data analysis, libraries and python bindings for scripting. It consists of set of components for pre-processing of data, exploration techniques, modelling, filtering, and feature scoring and model evaluation.

J. KNIME

It is an integration, reporting and open source environment. It's mostly utilized in pharmaceutical research and also in other domain like financial data analysis, business intelligence, and customer data analysis.

K. OCTOPARSE

This tool mimics human behavior to mine data and facilitates users to process website which needs login. IT supports developer to mine all kinds of hyperlinks from websites. This provide users an easy way to automate 100 of IPs and also provide various improvised options such as built-in XPath tools, Ajax timeout, etc. It crawl data for purpose of web search for particular request and transmit to structured data successfully.

Through this review, various web content mining (WCM) tools as well as its applications are analysed for the extraction of relevant information from the corresponding web page. Web Info Extractor, Screen-Scraper, Mozenda, Web Content Extractor, Automation Anywhere, SCRAPY, WEKA, Rapid Miner, ORANGE, KNIME and OCTOPARSE are the major WCM tools explored in this analysis. Various studies used different techniques of WCM which are Table I comparatively analysed and are explored to be content mining method on the basis of web-text mining, augmented information support etc. Applications of WCM are also revealed through this analysis and it has been found that automatic citation and indexing could be performed with the use of digital library with web mining methods; it can also be utilized to develop, arrange, classify and group most needed information which exist on internet. It also finds its relevance related to user query. On the other hand, challenges associated with WCM are discussed that mainly exhibits long user response time, tedious to execute the queries on non–homogenous data, security remains a major issue in WCM. Most of the analysed studies focused on various terms such as content formation, refusal index, pages number per visit, residence time etc. Quantitative analysis has not been concentrated on many studies. Hence, this study suggests focusing on quantitative analysis and integration of more number of WCM for providing a better perception regarding the significant web patterns.

TABLE I. COMPARATIVE ANALYSIS OF VARIOUS STUDIES ON WEB CONTENT MINING

S.no	Author	Description and methodology	Comments
1.	[26]	The study suggested a web content mining method on the basis of web-text mining to improve the efficiency. Further, the technique of AIS (Augmented information support) was employed to science based websites and developed AIS4XSSC text-mining system. This developed system was analysed for its efficiency, and the major functions are discussed.	The analysed results depicted that the augmented information support technology could efficiently extract the information from huge amount of web texts. Further, the suggested system can effectively improve the information retrieval and could provide valuable information to the users.
2.	[27]	This study suggested as well as implemented a novel web based solution called DAMIS, which was inspired by the cloud. Further, this enables the numerous data mining more effective and simpler for the business intelligence professionals and scientists.	This was beneficial for solving the dimensionality reduction, clustering and classification problems. The suggested solution has broad range of applications as well as provides in-depth information.
3.	[28]	The study suggested a support method as content lifecycle stages in the web systems.	Assists the implementation of web content support. This model described the information resources process in business system followed by the simplification of the automated support technology.
4.	[29]	The study attempted to overcome clustering problem through web document modelling in accordance with the labelled graphs. The study reduced the computational complexity by using the suggested algorithm.	This method promotes the modelling of the web documents without the elimination of contextual data followed by the clustering of these graphical objects with the suggested clustering algorithm.
5.	[18]	This paper provided a comprehensive description of the tools employed in web mining	The study failed to provide description regarding the OCTOPARSE tool. With the help of this study analysis of the stability, retention and usability of various tools could be performed.

VI. Applications

The following section describes few significant applications of web content mining. In general the cloud user utilize the web mining to extract relevant information form the cloud servers. E. commerce sites use these methods to obtain information regarding the specification of the corresponding products. Various search engines enable the user to explore billions of data and assign ranks for all the pages. Based on such ranking and user queries, the search engine orders and publish the pages. Further these techniques would help us to track the individual web sessions more effectively thereby providing valuable information regarding the user behaviour. The personalization plays a vital role for maintaining the confidential and personal information of the user.

Furthermore automatic citation and indexing could be performed with the use of digital library with web mining methods. Electronic services such as e-banking, online knowledge management, blog analysis, social networking, and personalization are used for providing recommendation to the customers. It is used in the crawling of social web platforms such as YouTube, Facebook and Flickr for the verification of the sociological concepts on a large scale for checking the complexity of the mathematical model. Apart from that terrorism is regulated through web mining since the terrorists utilize blogs, social networking, website forums, and virtual world for the exchange of information. By analyzing carefully, the data enable to regulate terrorism.

In addition, WCM is utilized to develop, arrange, classify and group most needed information which exist on internet. It also find its relevance related to user query. Most useful for online marketing by improved investigation of information on web. Users refine information with use of WCM, track online behavior of user, examine website productiveness and supports digital marketing over intelligence of product price, etc. Users having similar interest are club together and depending on examining the content they were posted on social media sites. Web mining technique is utilized to optimize online content since large quantity of content is added to WWW (World Wide Web) every day. Cloud managing with multiple videos, images and files must need to be optimized [30].

A. Limitations and Challenges

- When investigating the limitations of web content mining approaches, the following points are observed.
- Very long user response time. Accumulation of massive web resources leading to traffic.
- Any kind of solution for improvising the efficiency and quality might lead to the rise in bandwidth and cost.
- In case of web catching system, improper updation might cause bottleneck in servers, stale data and increase in the number of users.
- Still there exists no standardized tool to deal with over fitting, under fitting and oversampling of the data.
- There exists severe complexity in the elimination of duplicate data.
- The web content mining for time series data followed by its scaling up procedure seems to be complex.
- The mining of hyperlink network and structures are found to be difficult.
- It is tedious to execute the queries on non – homogenous data.
- Overall security remains a major issue.

In addition to that, mining one server is not useful so it needs numerous counts of servers to process and mine useful information. Special hardware and software were obligatory to extract terabytes of datasets. There is also chance of deleting new data from web with use of automatic cleaning process. There will be restricted inquiry interface, scope and customization to every clients. Some user needs more data than others or sometimes less than others or sometime there is need for extended data refining than prescribed. In some case its tedious task to search important information on web since it changes dynamically.

VII. Conclusion and Future Work

This paper deliberates the web content mining concepts, its classifications, and the associated major techniques. This survey also describe the data mining algorithm and methods for discovering the useful information from web. The application, recent trends followed by the limitations and challenges are also discussed in this paper. This paper also provide insight about the conventional web mining algorithms in simplifying the processing methods. This research explores various techniques, approaches and tools of WCM along with its applications and issues. Here researcher also establishes few objective criteria for comparison of WCM tools. WCM scans webpage content like text, video, audio, image and HTML content. Its output is supplied to search engine to develop most relevant knowledge. Since webpage consist of dynamic data it is a tedious process to extract data which is updated daily. In future, WCM must enhance its technique, approaches and tools to enhance scalability, usability and users retention. The future work focused on the integration of more number of web content mining for providing a better perception regarding the significant web patterns.

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Usability and Learning Environment of a Virtual Reality Simulator for Laparoscopic Surgery Training

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***Abstract*—One of the critical aspects of laparoscopic surgeries is the training and learning of medical students to acquire the experience and the correct use of the equipment, which is usually difficult due to different circumstances. One of the ways to improve these activities is by using Virtual Reality technology that allows immersion in scenarios that simulate reality, but to achieve its correct use, it is necessary to consider usability and its learning environment. This work aims to develop a simulator software in Virtual Reality that allows the training and learning of students in laparoscopic surgery, evaluating its usability and learning environment. The proposal was developed in five levels so that the student can have a greater concentration on each task; The levels developed are: clamps, clamps for the camera, cut, cut camera and cut with clamps; Each level has different tasks to perform with which the student will be able to interact in a more orderly way. The evaluation of usability and learning environment was carried out through the survey technique using the questionnaire instrument. The reliability analysis of the instrument was carried out using Cronbach's alpha test and using the correlation coefficient of its items by Spearman. The results showed that 85.85% of the surveys carried out were positive for the learning environment area and 81.18% of the positive surveys for the Usability area, so it is concluded that the proposal developed can help in the training of medical students procedurally and practically for the development of skills in laparoscopic surgery.**

***Keywords*—Usability; learning environment; virtual reality; training; simulator; medical; laparoscopic surgery**

I. INTRODUCTION

Laparoscopic or minimally invasive surgery is a surgical technique widely used today, either because it has few postoperative complications or because of the postoperative hospital stay [1]. However, for the mastery of this technique, it is necessary to adapt to the management of various instruments, techniques, and acquisition of skills, which can only be obtained through practice; this requires additional training in surgical skills to face advanced technological challenges [2]; currently, an alternative to this problem is acquired by the use of inanimate simulators, virtual simulators of high cost and direct management of patients in the operating room, which makes it difficult for doctors and students in general [3].

Virtual Reality (VR) simulations is a technology that has expanded in recent years with many advantages in different fields, such as medical education, by allowing virtual immersion in a given environment [4].

Besides, the interruption in the education of medical students during COVID-19 has been inevitable worldwide; for this reason, educational strategies must be developed to retain clinical skills, abilities, and knowledge [5], and that covers the limitations of the methods more traditional, especially in surgical procedures such as laparoscopic.

For this reason, the objective of this work is to develop a simulation software in Virtual Reality that allows the training and learning of students in laparoscopic surgery that allows them to practice challenging and significant procedures repeatedly and save the cost of training, evaluating its usability and learning environment; We will use tools such as Unity together with a helmet or glasses to generate three-dimensional images of simulated reality to allow immersion in a virtual medical environment. The usability and learning environment will be carried out through the survey technique using the questionnaire instrument. The reliability analysis of the instrument will be carried out using Cronbach's alpha test and using the correlation coefficient of its items by Spearman.

The rest of this paper is organized as follows: The second part is the background and related work. The third part describes the research material and method. The fourth part presents the results of this research. Finally, the conclusions and future work that has been reached with the study.

II. RELATED WORK

Different works on virtual reality were reviewed, its factors, oriented to the field of health, we highlight the most relevant.

The work of Pfandler et al. [6] carried out a systematic review of the current scientific literature regarding VR-based simulation in spinal surgery, where the quality of current studies and existing research is evaluated. In addition, to guide future studies evaluating virtual reality-based simulators in this field.

In the studies reviewed about student-oriented virtual reality simulation, Rizzo et al. [6] consider that this technology offers many advantages in the clinical area. Virtual environment technology provides a controlled stimulus where cognitive challenges can occur and the precise delivery and control of auditory and visual stimuli that simulate reality. Liou and Chang [7] developed a virtual reality classroom to improve student performance and learning outcomes. A virtual reality learning environment was developed, which integrates virtual reality technology, virtual reality devices, and 3D interactive virtual reality digital information content. To evaluate the effectiveness of the proposed design, students' performance in terms of learning achievement and learning motivation was examined. The results of this virtual reality classroom showed significantly better learning motivation.

Regarding the use of VR in the medical field, in the work of Izard, Juanes, and Penalvo [4] they point out that Virtual Reality is being integrated into many different areas of our lives, from video games to different cases of industrial use and, of course, it is beginning to be used in medicine; they analyzed how these systems can improve current methodologies used for medical training. VR has seen steady growth in medicine in recent years [8]. According to Chheang et al. [9], VR has been used in many medical training systems for surgical procedures. However, current systems are limited due to inappropriate interactions, restricted patient data visualization capabilities, and collaboration. So a collaborative virtual reality system can aid laparoscopic liver surgical planning and simulation.

For the virtual reality factors used in the simulations, the work of Servotte et al. [10] points out the factors that affect immersion and the feeling of presence in virtual reality. This study aimed to understand the elements that influence the sense of presence among undergraduate and graduate health students. The students were immersed in a simulated immersion in a mass casualty incident. Participants completed questionnaires before (propensity for immersion, stress) and after immersion (sense of presence, stress, cyberspace, and satisfaction). The results were that the sensation of presence was high among the evaluated groups and was positively correlated with the propensity to immerse.

A proof of the advantages of surgery training in virtual reality is the study by Vazquez-Minero et al. [11] performed on residents of cardiothoracic surgery, where a virtual reality simulator was used once a week for a total of 30 weeks where surveys were applied to measure the results, this study showed that the use of simulation as part of teaching is useful in the transmission and assimilation of knowledge, skills, and attitudes, however, in many specialties its use is just beginning, this is the case of chest surgery. A virtual reality simulator has also been created focused on bronchoscopy for residents of the independent specialty of the training year, achieving an improvement in their practices and safety after using the simulator. In conclusion, the use of simulation is an invaluable tool in the teaching process.

The paper of Jin, Dai, and Wang [12] indicates that virtual reality becomes popular in laparoscopic surgery, especially in the training process. The reviewed studies recommended applying virtual reality to inexperienced medical students or novice surgeons in laparoscopic training, where there was a steeper learning curve than traditional and untrained training.

For usability in VR environments, studies such as the one by Pierce et al. [13] determine the efficiency and satisfaction components of usability. Previously, it was found that first-year medical students who used a virtual reality simulation for medical education demonstrated effectiveness in learning. Training within the virtual simulation environment can be qualified as a practical educational approach [14].

Immersive VR laparoscopy simulation is emerging to enhance the attractiveness and realism of surgical procedure training. In the paper of Ganni et al. [15], the usability and presence of a virtual operating room were reviewed through user evaluation, and the critical elements for immersive environments were established during laparoscopic procedure training. Thirty-seven surgeons and surgical trainees performed the entire cholecystectomy task on the application. Questionnaires followed by a semi-structured interview were used to collect the data. The participants were able to adapt to the application intuitively and were satisfied with their tasks; the participants, particularly the surgical trainees, were very committed to performing the task. Despite the higher mental workload in four subscales ($p <; 0.05$), the surgical trainees had a lower learning effort (4 vs. 3.33, $p <; 0.05$) compared to the surgeons. The participants experienced very mild discomfort in seven body segments (0.59-1.16). Additionally, they expected improvements for team interaction and personalized experience within settings. The system showed potential to become a useful tool to provide immersive training during simulation of the laparoscopy procedure based on usability and presence observed in the study.

According to Taba et al. [16], VRS-based teaching is expanding in medicine due to the limitations of more traditional methods, especially for surgical procedures. There are already several areas, such as neurosurgery, ophthalmic surgery, and digestive endoscopy, considering implementing this technology in their training plans. The field of laparoscopic surgery also follows this trend, with conclusions that vary from study to study. Overall, the reviews conclude that RSV is a method with the potential to develop various surgical skills.

As described, most jobs vary according to the Virtual Reality approach to teaching college students. Of the reviewed studies, we saw that some are oriented to the medical field. Given the importance of adequately training and educating medical students, it is for this reason that the intention is to build an interactive virtual reality environment for simulated training in laparoscopic surgery.

III. Material and Method

For the construction of the medical VR simulator software, the agile Scrum methodology [17] will be used, which allows complying with the development of the application step by step of the proposed system, which was adapted according to the changing characteristics of the project. Fig. 1 shows a typical Scrum Project.

A. *Proposed Software Architecture*

Fig. 2. shows the software architecture that will be used to develop the VR simulator and how it provides support for the development of virtual reality applications and other Apps using the Unity multiplatform video game engine [19].

The proposal is focused on university-level students who can use virtual reality to learn the process of laparoscopic surgery. Two types of users have been identified: the student and the administrator.

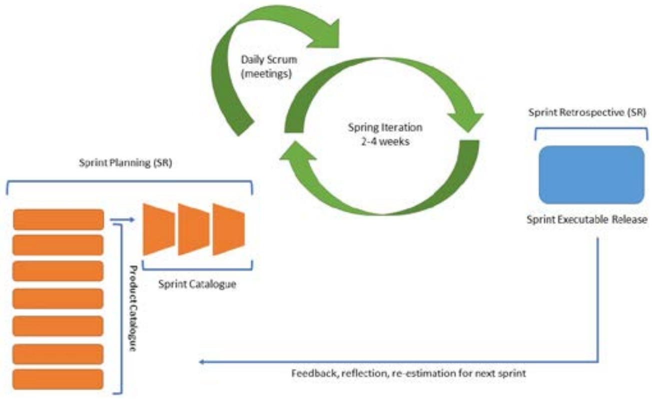

Fig. 1. Typical Scrum Project [18].

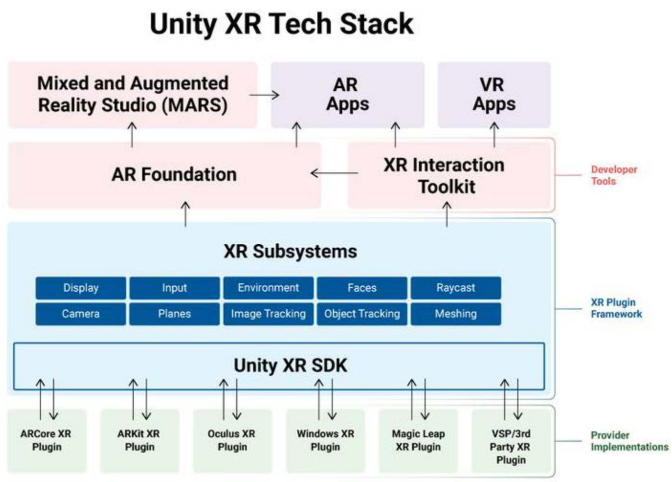

Fig. 2. Unity VR Application Software Architecture [20].

In terms of competencies and abilities, students must achieve learning progress defined by educational objectives focused on acquiring different competencies. The proposal consists of two sites, the virtual laparoscopic surgery environment, and the central system.

The student accesses different scenarios through the virtual reality glasses to carry out the training remotely, and an administrator will be able to access the information generated by the student with which they will evaluate their academic performance. This information is composed of the student's interactions in the virtual environment, the time it takes to perform the exercises, and feedback on her performance.

The interactions with the virtual environment are obtained based on the objects with which it interacts through the controls, the time is calculated from when the student begins the activity until it ends, and the performance feedback is measured based on the errors made. The student will send the information after finishing an activity; the information will be saved through a web database in which the information will be stored which can then be accessed through reports.

B. Components of the Proposed System

This section presents the details of the development of the proposed system and of each of its components. The connection of these components is seen in Fig. 3.

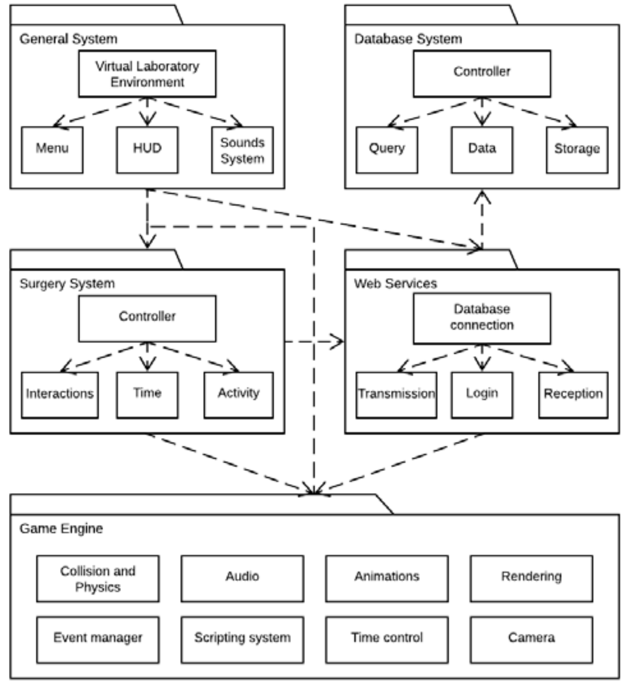

Fig. 3. Components of the Proposed System.

- General System: This is the essential component of the proposed system. Since it encapsulates all the necessary elements for the use of the application, such as the menus where you can standardize the pop-up windows and messages shown in the application, HUD which allows adapting the icons and buttons to the size of the screen, the sound system that allows the reproduction of background music and the reproduction of sound effects such as clicking buttons and, in the event that an activity is solved, a sound of success or error and the virtual environment where the operating room of a hospital is simulated, Different 3d models have been used to represent medical personnel, medical instruments and an operating room setting.

- Surgery System: This module contains a control that allows access to the different elements of each activity, allows assigning different actions to the controls, collecting the information from the controls, and generating different actions according to the type of tool selected; it also controls the time to complete each activity, how the elements of the environment react before user interactions and if the activity has been completed.

- Web service: This module is responsible for the reception and transmission of data between the application and the web database, analyzes the user's interactions to the system, and is stored in a predefined database table on the server, the benefit of using a database. Web data it is possible to share the information of different clients.

- Database server: A web database server that stores information in predefined tables and responds to queries when necessary. To access the server, access is given.
- Game Engine: This module contains all the functions that are carried out in the development software such as collision and physics system, audio control, image rendering system, an event handling system, a scripting system for code handling, a controller of time that allows controlling the time that has elapsed and a canvas system with which the menus are controlled.

C. *Implementation of the Proposed System*

The proposed system has been implemented as a prototype of which the software used for development will be explained, the requirements to be used, and a scene where laparoscopic surgery training is carried out.

The software used for the development of the proposed system was the Unity game engine; the system was created in conjunction with professors from the medical area of the Universidad Católica de Santa María (UCSM) of Arequipa-Peru; the activities of the system were based on the training carried out in the laboratory practices.

The system hardware consists of a computer that has an i5 processor or similar, an NVIDIA GTX 1060 or similar graphics card, which will be used in conjunction with an Oculus Rift that allows the use of virtual reality and interaction with the system; it was decided choose the oculus rift because wanting to simulate the interactions of medical students with surgical instruments requires greater precision and realism [21].

Before using the application, the user must calibrate the Oculus Rift, which has different sensors that must be connected to the computer and create the workspace.

D. *Virtual Laparoscopic Surgery*

The application will teach students about how to use medical instruments to perform the surgery correctly; the application will have different levels which represent the learning sessions where different tools will be used; we will describe the activity of each level below:

- Tweezers activity: It is the first level of the lessons, in which students learn to use the tweezers to pick up objects in the virtual environment; the tweezers will be represented with a realistic model which will be animated and move according to how the virtual reality control is pressed, In this activity, you will be given a series of objects that the player must place on a metal tray, the player must control the pressure that he gives to the clamp in order to avoid damaging the object or that it slips from the tweezers as seen in Fig. 4.

Fig. 4. Tweezers Activity Scene.

- Camera tweezers activity: In this second level, the use of tweezers will continue, but instead of working with a visible object in the scene, it will be done with an object that can only be seen through a monitor; this is done to simulate how it is done. When having a limited vision of the object in surgery, the student will have to remove the object and place it on a tray, avoiding that it falls, as seen in Fig. 5.

Fig. 5. Camera Tweezers Activity Scene.

- Cut activity: In this third level, the student must change the tool to be used and select a scalpel with which he must cut an object in different selected areas, as shown in Fig. 6.

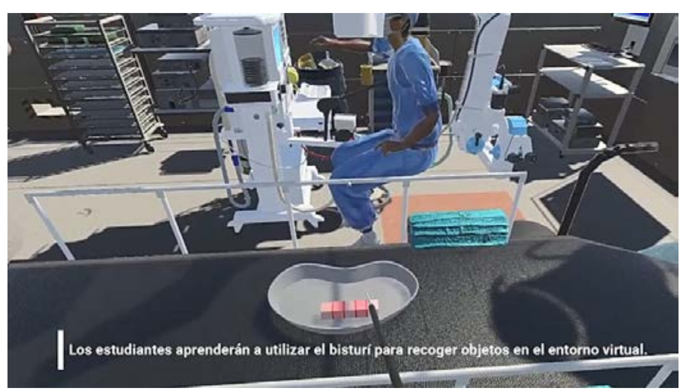

Fig. 6. Cut Activity Scene.

- Camera cut activity: In this fourth level, the student must use the scalpel to make cuts in specific areas of an object, but to carry out this activity, the student will have limited vision since they can only see the object through a monitor, as shown in Fig. 7.

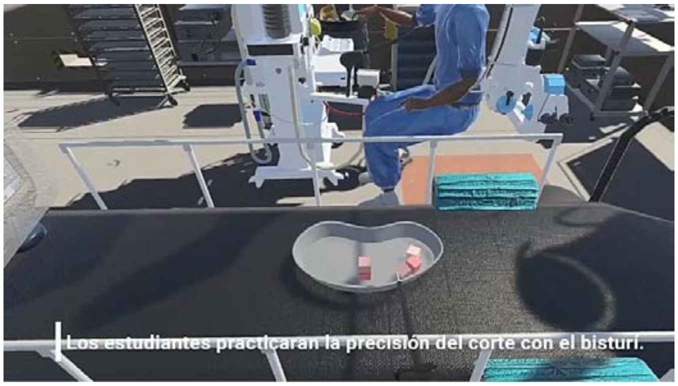

Fig. 7. Camera Cut Activity Scene.

- Tweezers and cutting activity: In this fifth level, the student must collect objects with the use of tweezers and with the other hand uses a scalpel to cut the object in order to extract it; at this level, the player will use both hands to extract an object, After having removed the object, it should be placed on a tray as shown in Fig. 8.

Fig. 8. Tweezer and Cut Activity Scene.

IV. RESULTS

Participants in the experiment were surveyed to measure their learning in virtual environments and usability in virtual reality applications and the problems encountered.

The questionnaire used was to respond mainly to two research questions 1) to evaluate users' attitudes towards the VR application as a learning environment; and 2) to evaluate the usability of the VR application. Users are evaluated on the measurement items for each point.

A. Learning Environment

To evaluate the learning environment, eleven measurement categories are being used, which can be observed in Table I [22].

TABLE I. CRITERIA OF LEARNING ENVIRONMENT

N°	Measurement Items
1	Immersion in the application
2	Realistic learning
3	Interaction with objects
4	Educational Utility
5	Ease of use of the application
6	Feeling of being there
7	Motivation in learning
8	Intention to use the application
9	Cognitive benefits
10	Perceived Learning Effectiveness
11	Satisfaction when using the application

B. Usability of Virtual Reality Applications

To evaluate usability, usability heuristics were analyzed, and 12 measurement categories are used, as shown in Table II [23].

Twenty-seven surveys were conducted made up of students, teachers, and graduates of the UCSM medical career. The responses were categorized within a Likert-type scale, with values from 1: Disagreement to 5: Agree. Taking the results of the surveys, we obtained that in the Learning Environment, the respondents partially agree with the application, having a percentage of 49.49%, as can be seen in Fig. 9.

In the area of learning environment, it was obtained that in the question "Ease of use of the application: Was the application understandable and did you manage to understand it easily? More positive responses were obtained from our application, which 51% are "Agree" and 44% "Partially agree," obtaining only 5% negative responses, instead of the question Satisfaction when using the application: Are you satisfied with the learning experience that educational software provides? " is where we need to improve in our application.

TABLE II. USABILITY CRITERIA FOR VIRTUAL REALITY APPLICATIONS

N°	Criteria
1	Level of realism in the virtual environment
2	Level of realism when performing tasks
3	Freedom of movement
4	Response time on the screen
5	Realism in physics
6	Perception level
7	Navigation level and orientation
8	Ease of iput and output
9	Understandable menu
10	Ease of use
11	Organized and understandable tasks
12	Presence

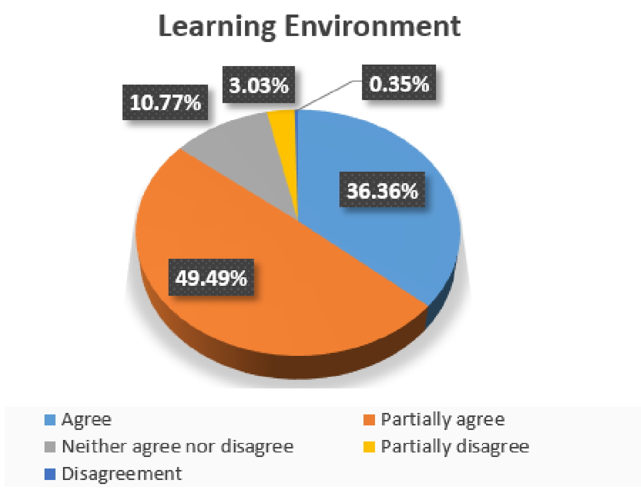

Fig. 9. Results of the Surveys on the Learning Environment.

Regarding the usability of virtual reality, we obtained that the respondents partially agree with 53.40%, as can be seen in Fig. 10.

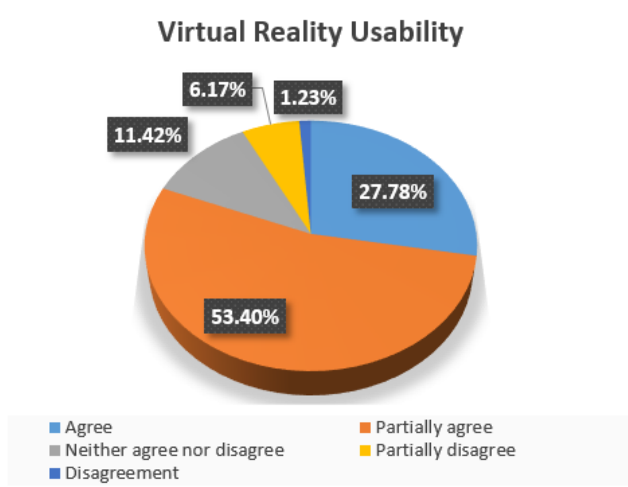

Fig. 10. Results of Surveys on the usability of Virtual Reality.

In the area of virtual reality usability, it was obtained that in the question "Tasks organized and understandable, do you consider that the tasks in the simulator are organized and understandable to complete the activity?" The most positive responses of the application were 55% for "Agree" and 44% "Partially agree," obtaining only 1% negative responses, on the other hand, in the question "Feeling of being present in the virtual world: Do you feel that you are present in the virtual world in a natural way? " it is where it has to be improved in the proposed VR application.

The reliability of the internal consistency of the measurement elements of the questionnaire was evaluated by calculating Cronbach's alpha (α) test based on the variance of the instrument items [24]. Alpha reliability was considered acceptable, with values ranging between 0.832 for the Learning Environment (Table III) and 0.898 for the Usability of Virtual Reality (Table IV). In addition, the mean and standard deviation (S.D.) of the elements have been generated.

The Spearman correlation was also performed between each measurement item of the Learning Environment and Usability of Virtual Reality measurement; the results are presented in Table V and Table VI, respectively. For the analysis of the results, the SPSS 26.0 software package was used.

There was a medium to strong positive correlation (> 0.3) among the majority of items with the VR characteristic of Representational Fidelity regarding the learning environment. Perceived Learning Effectiveness and Satisfaction showed a small to medium correlation effect with immersion.

Regarding usability, there was also a positive medium to strong correlation between most items. The Freedom of movement showed a small to medium correlation effect with realism in the virtual environment and with the level of realism when performing tasks.

TABLE III. QUESTIONNAIRE MEASUREMENT ITEMS: LEARNING ENVIRONMENT

N°	Measurement Items	α	Mean	S.D.
1	Immersion in the application	.907	4.15	.534
2	Realistic learning	.879	4.22	.698
3	Interaction with objects	.898	4.07	.730
4	Educational Utility	.882	4.37	.688
5	Ease of use of the application	.886	4.44	.641
6	Feeling of being there	.890	4.07	.675
7	Motivation in learning	.896	3.96	1.01
8	Intention to use the application	.877	4.30	.775
9	Cognitive benefits	.889	4.30	.724
10	Efficiency of the application in learning	.876	4.19	.962
11	Satisfaction when using the application	.893	3.96	.854

TABLE IV. QUESTIONNAIRE MEASUREMENT ITEMS: USABILITY

N°	Measurement Items	α	Mean	S.D.
1	Level of realism in the virtual environment	.815	3.96	.706
2	Level of realism when performing tasks	.820	3.93	.675
3	Freedom of movement	.817	3.81	.962
4	Response time on the screen	.810	4.00	.961
5	Realism in physics	.804	3.85	1.06
6	Perception level	.806	3.59	.888
7	Navigation level and orientation	.814	4.04	.759
8	Ease of input and output	.814	3.89	.892
9	Understandable menu	.826	4.37	.688
10	Ease of use	.829	4.44	.577
11	Organized and understandable tasks	.832	4.52	.580
12	Presence	.831	3.63	1.04

TABLE V. SPEARMAN CORRELATION BETWEEN THE MEASUREMENT ITEMS LEARNING ENVIRONMENT

N°	Measurement Items	1	2	3	4	5	6	7	8	9	10	11
1	Immersion	1										
2	Representational Fidelity	.196	1									
3	Immediacy of Control	.287	.332	1								
4	Perceived Usefulness	.140	.705	.414	1							
5	Perceived Ease of Use	.247	.501	.579	.818	1						
6	Presence	.536	.589	.394	.408	.288	1					
7	Motivation	.125	.697	.259	.612	.458	.363	1				
8	Cognitive Benefits	.146	.641	.489	.761	.762	.570	.657	1			
9	Intention to use system	.351	.506	.403	.495	.500	.611	.286	.677	1		
10	Perceived Learning Effectiveness	.087	.849	.353	.771	.637	.477	.574	.721	.579	1	
11	Satisfaction	.047	.455	.441	.441	.443	.508	.463	.572	.348	.495	1

TABLE VI. SPEARMAN CORRELATION BETWEEN THE MEASUREMENT ITEMS USABILIDAD OF VIRTUAL REALITY

N°	Measurement Items	1	2	3	4	5	6	7	8	9	10	11	12
1	Level of realism in the virtual environment	1											
2	Level of realism when performing tasks	.332	1										
3	Freedom of movement	.196	.287	1									
4	Response time on the screen	.705	.414	.140	1								
5	Realism in physics	.501	.579	.247	.818	1							
6	Perception level	.589	.394	.536	.408	.288	1						
7	Navigation level and orientation	.697	.259	.125	.612	.458	.363	1					
8	Ease of entry and exit	.641	.489	.146	.761	.762	.570	.657	1				
9	Understandable menu	.506	.403	.166	.495	.500	.611	.286	.677	1			
10	Ease of use	.849	.353	.064	.771	.637	.477	.574	.721	.579	1		
11	Organized and understandable tasks	.455	.441	.068	.441	.443	.508	.463	.572	.348	.495	1	
12	Presence	.433	-.190	.224	.126	-.003	.452	.291	.356	.448	.388	.067	1

V. DISCUSSION AND CONCLUSION

Evaluating the virtual reality simulator for laparoscopic surgery, in terms of its usability and learning experience, is very important for the successful acceptance of the training in medical students. This study used usability heuristics in 12 measurement categories and 11 measurement categories for the learning environment.

In essence, the virtual reality simulator developed and proposed presented an acceptable acceptance of usability among those who agreed (27.78%) and partially agreed (53.40%), as well as for the learning environment among those who agreed (36.36 %) and partially agreed (49.49%). These results show a high level of validity, as do other studies that assess the acceptance of usability and learning environment in a virtual reality simulator for laparoscopic surgery[23], thus, in a study carried out in England, with a laparoscopic cholecystectomy training simulator, ten doctoral students and five volunteers from the department of general surgery were interviewed, among laparoscopic students and experts, to find out their perceptions about the usefulness of a procedure. simulator to help you better understand the surgical procedure of a cholescitectomy and practice surgical skills as well as decision making at the operative stage. Participants were asked to analyze the performance of a laparoscopy simulator; using 5five criteria: "ease of use, interactivity, visual realism, freedom of movement and effectiveness, and system stability" [2]; they concluded that game engine is an option with highly interactive virtual surgery training platform for pedagogical purpose, however, improvements are required to simulate and improvement in anatomy precision, as the different layers of tissues that a surgeon must actually operate in real surgery, the visual realism the integrity of procedure and the guide of medical experts [2].

Our results are consistent with various studies that showed that reality simulation virtual is significantly more effective than video trainers, as in the systematic review and meta-analysis of 31 randomized controlled trials, in which virtual reality training was compared with other training models or with no training; this meta-analysis concludes that “virtual reality simulation is significantly more effective than video trainers and at least as good as box trainers” [25]. In addition, other studies that investigated similarly to the present study recommended applying virtual reality to inexperienced medical students or surgeons novice in laparoscopic training [12].

The COVID 19 pandemic has changed paradigms in medical education, being an important change, suspension of face-to-face medical education [26] and in the case of medical internship, reducing direct contact with patients, to minimize the risks of contagion: In this scenario, the use of telemedicine, tele-teaching [27] and the use of simulators for medical education, is essential [28]. A key challenge for medical schools will be to simulate clinical encounters, between doctors, students and patients, therefore, proposals for the development of medical and surgical simulators and their respective socialization, evaluation, validation and technology transfer, are actually the steps to follow in the face of this health emergency scenario and in the future in the face of new similar pandemic scenarios.

The reliability of the internal consistency of the measurement elements of the questionnaire was evaluated by calculating Cronbach's alpha (α) test. Alpha reliability was considered acceptable, with values ranging between 0.832 for the Learning Environment and 0.898 for the Usability of Virtual Reality.

In this sense, the deductive and/or confirmatory approach of the proposed simulator for laparoscopic surgery training in virtual reality was mainly valid according to the results found.

These results support the incorporation of these virtual learning technologies based on simulation in medical education, especially in these times of health emergency. As concluded in the study "Simulations and Virtual Learning Supporting Clinical Education During the COVID 19 Pandemic", which indicates the urgent need to considering the benefits of simulation-based healthcare environments in Medical schools [28].

In conclusion, a simulator based on virtual reality was developed, allowing the training of laparoscopic surgery practices to medical students as a different alternative in a virtual world with different levels of manipulation. The environment that was recreated with the simulator creates an environment for learning and usability suitable for medical students by having simulated a realistic environment; this is due to Unity, which was very supportive in terms of the textures of the elements and the models used. Virtual reality technology was successfully used in the educational field since both the hardware and software parts were combined in this project and the sensors to interact with the entire virtual environment and the 3D models and animations. The results showed that 85.85% of the surveys carried out were positive for the learning environment area and 81.18% of the positive surveys for the Usability area, so it is concluded that the proposal developed can help in the training of medical students procedurally and practically for the development of skills in laparoscopic surgery.

As future work, it is suggested that more in-depth studies be carried out that allows increasing the correlation of Measurement Items Perceived Learning Effectiveness and Satisfaction with Immersion for the learning environment, as well as between Freedom of movement with the level of realism in the virtual environment. and with the level of realism when performing tasks.

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Detection of Hepatoma based on Gene Expression using Unitary Matrix of Singular Vector Decomposition

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***Abstract*—Hepatoma is a long-term disease with a high risk of mortality. However, the disease is late detected, at the fourth level stadium due to silent symptoms. The infected hepatitis B virus gene *HBx* is a genome virus to trigger liver disease. This virus inserts material genetic into the host and disturbs the cell cycle. The regulation of gene expression is blocked to make work abnormal, especially for repairing and degrading. A microarray is a tool to quantify the RNA gene expression in huge volumes without any information for the related potential gene. Therefore, this study is proposed a feature extraction method using a unitary singular matrix for simplifying the classification model of hepatoma detection. Principally, the feature is decomposed using a singular vector to get the *k*-rank value of pattern. This matrix is applied to the representative machine learning algorithm, including KNN, Naïve Bayes, C5.0 Decision Tree, and SVM. The experimental result achieved high performance with Area under the Curve (AUC) of above 90% on average.**

***Keywords*—Hepatoma; gene expression; feature extraction; unitary matrix**

I. Introduction

Hepatoma is a liver disorder disease and progresses from chronic, acute, cirrhosis to over a long period of about 30-40 years to liver cancer. This type of disease has a high number compared to cancer as a cause of death. Many studies carried out an early detection because of silent symptoms. The disease is detected after the third to fourth stadium stages. In the biology field, the relationship between mutations or genetic variations of the hepatitis B virus and liver cancer is open research and is still being debated.

Another hand, the infected virus affects abnormal gene expression regulation. An infected virus is a cause of Hepatoma disease and blocks the expression for reparation or destruction in the cell cycle. However, the new genes are produced uncontrol-up to trigger the oncogene in high volume. A microarray is a tool to investigate and quantify gene expression. The large number of genes involved in screening requires further analysis to get any information inside the genes.

The large volume of gene expression effected to high dimensional data. It required high space memory and high-speed in computation time to construct a classifier model for hepatoma detection. Therefore, many studies applied feature reduction methods to construct modeling data for the disease detection. The methods are including clustering, hybrid SFS and LASSO, Random Forest, and Dynamic Bayesian Network or using bioinformatics tools with a statistical approach to obtain information on significant differences in gene expression and then used as features to implement in classifier model of machine learning algorithms for detection [1]–[8].

Basically, there are two methods for reducing data volume including feature extraction and feature selection to simplify the machine learning model. Many studies on hepatoma detection are based on gene expression using feature selection for dimension reduction. However, the feature selection affects loss information. Therefore, this research aims to reduce the dimensional data using feature extraction method through the singular vector decomposition to get a unitary matrix. The matrix contains eigen value and indicates important information of pattern of data collection with certain *k*-rank value.

This paper consists of five sections. The first section is provided the background of this study. Then, the previous related research and research gap are described in Section 2. The proposed method and basic concept are performed in Section 3. The result and discussion are provided in Section 4. Last, the conclusion and future work are prepared in Section 5.

II. Related Work

Research on hepatoma disease detection using gene expression is related to the high dimensional data. Many studies applied to reduce the dimensional data to simplify learning model for detection. The maximum redundancy minimum relevance (mRMR) is a method to identify the significant gene as biomarker in hepatoma mechanism [6]. Then. Markov clustering method was applied to identify liver cancer module biomarkers from gene expression GSE20948 and achieved the AUC rate of 0.875 [3]. Also, a dynamic Bayesian network feature selection was applied to SVM classifier for the diagnosis of liver cancer using data set under geo access number GSE17856 and achieved high accuracy [2]. Another research for feature selection method was Hybrid Forward Selection of the LASSO technique was applied to the SVM algorithm for liver cancer disease classification. It achieved an accuracy rate of 98.2% [1]. Then, Zhang et.al (2020) researched gene expression microarray data including GSE54236, GSE6404, GSE121248 for early diagnosis of liver cancer using an SVM classifier that combined Maximum Redundancy and Minimum Relevance (mRMR) feature selection method, and the results achieved a high performance [6]. Recently, the reduced data is also applied by removing unrelated features and identifying the significant gene expression using machine learning method and statistical approach [7]–[9]. However, all those studies aimed to select the feature for dimension reduction. The omitted data is an effect to integrated information. Therefore, this research is proposed feature extraction by transforming the gene expression values in unitary matrix using the singular vector decomposition approach. The matrix contains important information and delineates the data collection.

III. Material and Research Method

A. Data Set

The data set of human gene expression in this study is taken from the data bank National Center for Biotechnology Information (NCBI) at URL: https://www.ncbi.nlm.nih.gov/geo/. They used a blood cell platform (GPL15491) and a liver tissue platform (GPL570) with GEO access numbers GSE114783, GSE55092, and GSE121248. Refer to the biological network approach, the data GSE114783 is addressed to investigate potential mechanisms and biological markers of every stage from HBV infection to hepatoma. Global gene profiling methods of healthy individuals (HC), HBV carrier (HBVC), chronic hepatitis B (CHB), liver cirrhosis (LC), and hepatoma (HCC) patients were analyzed by sequencing gene [10].

The different gene expressions were found by corrective RVM (Random variance model) analysis of ANOVA and STC (Series Test of Cluster). Mononuclear blood cells (PBMC) from three healthy people (HC), three HBV carriers (HBVC), three chronic hepatitis B (CHB) patients, three liver cirrhosis (LC), and three hepatomas (HCC) samples as the details shown in Table I, two data sets are under platform liver tissue (GPL 570) including GSE55092 and GSE121248. The sample GSE55092 is identified molecular and genomic of Whole Liver Tissue (WLT) of 17 samples and Laser Capture-misdirected (LCM) of 11 samples. In these samples, the gene was applied to profiling the WLT at any distance from the centroid of the tumor. They were taken from 11 patients' liver cancer using the selected LCM samples [11]. Another sample GSE121248 consists of the profiled gene expression under platform blood cell [12]. The two kinds of these samples are taken from liver tissue, either liver cancer-induced by Hepatitis B chronic or normal tissue in the adjacency of Affymetrix construction.

TABLE I. THE DATA SET DETAILS

Data sets	Total features	Class (number of data)
GSE114783 (GPL15491)	30142	Liver cirrhosis (10), healthy control (3), chronic hepatitis B(10), hepatitis B virus(3), HCC (10)
GSE55092 (GPL 570)	54.676	Whole Liver Tissue (120), malignant hepatocytes (10), non-malignant hepatocytes (10)
GSE121248 (GPL 570)	54.676	Adjacent Normal sample (37), tumor sample (70)

B. Research Method

Research on Hepatoma detection through machine learning methods using gene expression microarray data is a big data problem. The large size of the gene as a feature affects data modeling in building classification algorithms to make it so complicated and time-consuming. The number of gene expressions (*m*) is much more than the number of data (*n*). In another word, we can notate as (m>>n) as illustrated in the following matrix.

$$\begin{bmatrix} A_{11} & \cdots & A_{1m} \\ \vdots & \ddots & \vdots \\ A_{n1} & \cdots & Anm \end{bmatrix} \quad (1)$$

Therefore, this research is proposed to reduce dimensional data by feature extraction. The extraction is carried out to find patterns of gene expression differences in the hepatoma mechanism. The related method used in this research is dimension reduction through feature extraction using singular vector decomposition (SVD) and principal component analysis (PCA). Generally, the main stages of the proposed method are described in Fig. 1.

1) Singular Value Decomposition (SVD): A microarray of gene expression is represented by a matrix of associated genes from the host. For example, there are m gene expressions and n hosts (samples), it can be made m x n sample-genes as matrix A for the total RNA formed. SVD is a Latent Semantic Indexing method to find patterns in a matrix and identify gene expressions that are similar to one another. This section describes some of the basic components of the SVD used as a dimensional reduction method. Making a new matrix from matrix A with m gene expression x n hosts which is a matrix of U, $\sum$ and V so that $A = U\sum V^T$ can be illustrated as in Fig. 2. U and V are unitary and orthogonal matrices that have unit columns so that $U^TU=I_m$ [8].

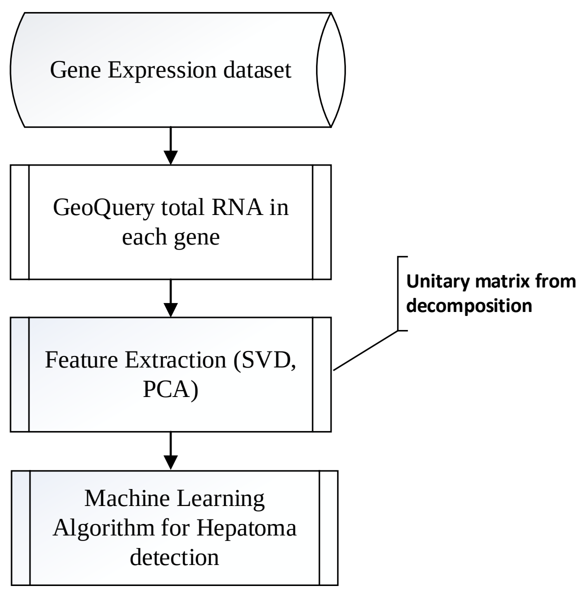

Fig. 1. Flowchart of General System for Hepatoma Detection.

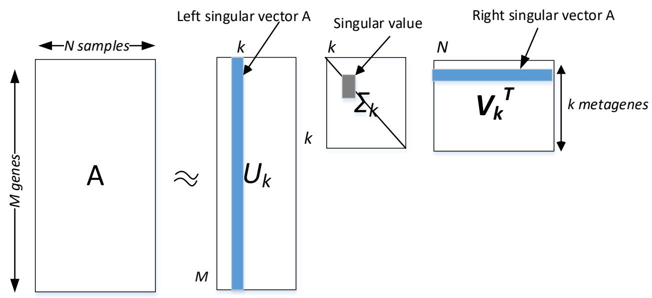

Fig. 2. Reduced Dimension Representation of the Genes-Samples Matrix.

Then, the proposed method of feature extraction using unitary matrix in SVD has several steps are as follows:

a) Compute its transpose A^T and A^TA.

b) Get the eigenvalues of A^TA and arrange these in descending order, in the absolute sense. Then, compute the square roots to obtain the singular values of *A*.

c) Construct a diagonal matrix $\sum$ by placing singular values in descending order along its diagonal. After that, compute its inverse, $\sum^{-1}$.

d) Use the ordered eigenvalues from step b and compute the eigenvectors of A^TA. Put these eigenvectors along with the columns of *V* and count its transpose, V^T.

e) Compute membership matrix *U* as $U=AV\sum^{-1.}$

f) Matrix *U* with *k*-rank as dimension is used as data set to construct classifier model of machine learning algorithm.

2) Principle Component Analysis (PCA): Another way to reduce the matrix dimension is of Latent Semantic Indexing (LSI) is to use principal component analysis (PCA). The main goal of PCA is to acquire a new set of dimensions (features) that better capture data variability. The first dimension is chosen to capture as much variability as possible. The second dimension is orthogonal with the first dimension capturing as much of the remaining variability as possible, and so on. Hence, the strongest pattern is found in the first dimension as [13]. As an illustration, the PCA is implemented to decompose gene expression-samples matrix for reduction as shown in Fig. 3.

Generally, this method obtains the eigenvector and eigenvalues from the covariance of matrix *A*, as stated in detail below:

a) Construct an $N \times d$ document-term matrix *A*, with one-row vector A_n per data point.

b) Then matrix *A* subtract mean is multiplied from each row vector A_n in *A*.

c) Get the covariance matrix *Y* of *A*.

d) Find eigenvector and eigenvalues of *Y*.

e) The principal component is obtained from *M* eigenvectors with the largest eigenvalues.

The PCA is known for applying Singular Vector Decomposition (SVD) on the covariance matrix. Here, the illustration of PCA for document-term matrix *A* is shown in (2).

$$\begin{aligned}
&A \rightarrow Y, \text{ where } Y = A_i - \mu_j \\
&Y \rightarrow Y^T \\
&1/(n)\, Y^TY \rightarrow A \\
&A \rightarrow U\Sigma V^T
\end{aligned} \qquad (2)$$

3) Machine learning algorithm: A machine learning algorithm is a generated method from data collection to construct a pattern for prediction or description. The algorithm is a way to make computer programs that increase performance based on its experience [14]. In this research, the method is addressed for the classifier model for hepatoma detection. Some various representative machine learning algorithms are applied including hyperplane function (Support Vector Machine), probability-based (Naïve Bayes), similarity-based (*k*-Nearest Neighbor), entropy-based (C5.0 Decision Tree), an ensemble method for aggregation (Random Forest).

a) Support Vector Machine (SVM): Support Vector Machine (SVM) algorithm is a supervised machine learning method for classification that desires to get the optimal hyperplane function. Initially, the function is to define two classes (binary class) in a linear function. Then, it was developed into non-linear classifiers by involving kernel tricks in the high dimension. The data is transformed into a high dimension of vector space [15].

b) Naïve Bayes Classifier: Another supervised learning method based using the statistical approach is the Naïve Bayes algorithm. This method used probability theory. Naïve Bayes Classifier is a simple classification method based on the Bayesian probability theorem. The main character is a very strong (naïve) assumption of independence from each event. The model is easy to create using this formula as in (2) [16].

$$P(C|X) = \frac{P(C)P(X|C)}{P(X)} \qquad (3)$$

where *X* is attributed, *C* is class.

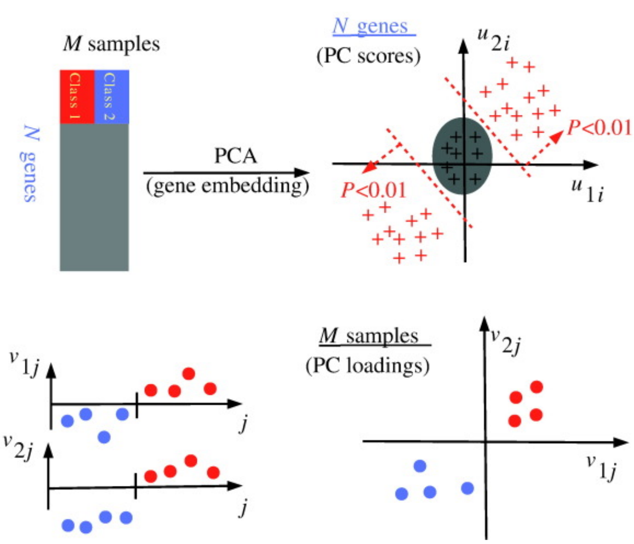

Fig. 3. Principle Component Analysis of Gene Expression Data Set.

c) K-Nearest Neighbor: *K*-Nearest Neighbor is a supervised learning method based on the distance or similarity of an object's characteristics. The algorithm decides the class of data points from the training data whose similar enough. The class of new data object is chosen in *k* closet data and is taken in the majority vote of class from training data [17].

d) C5.*0 Decision Tree:* C5.0 is a supervised learning algorithm that constructs a tree based on entropy value to build decision rule. This algorithm is an extension of Decision Tree 4.5 with a simpler tree (rule set) that is built so that the steps taken are more concise. This method is better than the previous Decision Tree method, ID3, and C4.5 for pruning and memory allocation (space complexity) [18]. The difference between C5.0 and C4.5 is the boosting and voting processes to determine the class based on the calculation of a combination of several trees.

e) Random Forest: Random forest (RF) is an enhanced method of a decision tree that is built using aggregating several trees. The trees are grown without pruning during training [19]. The algorithm is a decision tree method similar to the Classification and Regression Tree (CART) method with maximum size without pruning. The scheme resembles bagging in the training data set to build a new tree. To predict the new data, it collects the class from several trees.

4) K-Fold Cross-Validation: *K*-fold cross-validation is a method used to evaluate the performance of experimental results. The whole data are divided by *k* parts, then they are iterated for *k* iterations in the different folds. In this research, the total number of folds (*k=10*) will be divided into two parts, namely training and testing data. In the testing data used as *m* fold, and in the training, data used as *k-m* fold. Each fold will be filled with class +1 and class -1 data within a proportion [20].

IV. Result and Discussion

A. Experimental Result

Several representative machine learning algorithms are used to evaluate the performance of feature extraction. The representative machine learning algorithms are including KNN, Naïve Bayes, SVM, C5.0 Decision Tree, and Random Forest. Three data sets GSE114783, GSE55092, and GSE121248 were applied to decompose the matrix using the proposed method (SVD and PCA) for dimension reduction. Thus, they were applied to the representative machine learning using k-fold cross-validation, and as a result, the performance including accuracy, sensitivity, specificity, and AUC was shown in Table II, Table III, and Table IV.

In Table II, the SVM and RF are stable and achieve the highest performance of 1 (100%). It means that both algorithms do not depend on the data distribution and the number of data sets. However, the worst classification is using the K-NN algorithm with *k*-nearest value =3. The accuracy and sensitivity achieved the lowest of 58% using original data (without dimension reduction). It shows that the performance proposed method is dominant in any representative machine learning algorithms.

In Table III, the performance result including accuracy, sensitivity, and specificity is highest at SVM and RF algorithms. In contrast, the specificity of KNN is the lowest. It means that the ability to classify in a negative class is not good. The reduction using PCA method is slightly better than the others.

TABLE II. PERFORMANCE COMPARISON OF THE PROPOSED METHOD USING REPRESENTATIVE MACHINE LEARNING ALGORITHMS ON GSE114783

Perform. Measure	Reduct Method	Machine Learning Algorithm				
		SVM	**NB**	**RF**	**K-NN**	**C5.0**
Accuracy	SVD full	1	0,94	1	0,61	0,89
	SVD k=20	1	0,83	1	0,69	0,86
	PCA	1	0,94	1	0,61	0,89
	no-FS	1	0,72	1	0,58	0,97
Sensitivity	SVD full	1	0,94	1	0,61	0,89
	SVD k=20	1	0,83	1	0,69	0,86
	PCA	1	0,94	1	0,61	0,89
	No-FS	1	0,72	1	0,58	0,97
Specificity	SVD full	1	0,98	1	0,86	0,96
	SVD k=20	1	0,94	1	0,9	0,94
	PCA	1	0,98	1	0,87	0,96
	No-FS	1	0,89	1	0,86	0,99
AUC	SVD full	1	0,95	1	0,73	0,92
	SVD k=20	1	0,89	1	0,8	0,90
	PCA	1	0,96	1	0,74	0,92
	No-FS	1	0,81	1	0,72	0,98

TABLE III. PERFORMANCE COMPARISON OF THE PROPOSED METHOD USING REPRESENTATIVE MACHINE LEARNING ALGORITHMS ON GSE55092

Performance Measure	Reduction Method	Machine Learning Algorithm				
		SVM	**NB**	**RF**	**KNN**	**C5.0**
Accuracy	SVD full	1	0,9	1	0,86	0,97
	SVD k=10	1	0,88	1	0,93	0,98
	PCA	1	0,9	1	0,93	0,97
	no-FS	1	0,957	1	0,921	0,993
Sensitivity	SVD full	1	0,897	1	0,857	0,969
	SVD k=10	1	0,879	1	0,929	0,977
	PCA	1	0,897	1	0,929	0,969
	No-FS	1	0,957	1	0,921	0,993
Specificity	SVD full	1	0,992	1	0,143	0,913
	SVD k=10	1	0,779	1	0,571	0,914
	PCA	1	0,992	1	0,614	0,957
	No-FS	1	0,997	1	0,529	0,99
AUC	SVD full	1	0,945	1	0,500	0,941
	SVD k=10	1	0,829	1	0,750	0,945
	PCA	1	0,945	1	0,771	0,962
	No-FS	1	0,977	1	0,725	0,975

Then, in the last experiment of data set GSE121248, two algorithms including SVM and RF are stable and achieve the highest performance of 100% (1). In contrast, the lowest performance is at KNN algorithm in SVD without using k-rank for accuracy and the Area Under the Curve (AUC). However, the proposed method using SVD with *k*-rank=10 is high performance in accuracy, sensitivity, and specificity as shown in Table IV.

Furthermore, the proposed method of dimension reduction using SVD with *k*-rank value has maximum the number of a dataset (SVD full). It means that there are *k* patterns of gene expression data collection. In the data set GSE55902 and GSE121248, the variance pattern is notated as eigenvalue and converges at the first 10 singular values as shown in Fig. 4. However, the eigen value convergence of GSE114783 is in the first 20 values as shown in Fig. 5, The variance pattern values indicate significant feature values.

Another hand, in PCA method, the characteristic of dimension values has convergence starting from 10 variances data as shown in Fig. 6. The larger the value of *k*-rank, the smaller the data variance is.

Then, the computational time required for the hepatoma detection using the machine learning algorithm representation in this study appears so much short, due to a large number of reduced features. The reduction of computation time is very significant in the Naïve Bayes algorithm, then C5.0 Decision Tree and Random Forest. The comparison of computational time on the machine learning algorithm using the proposed method is shown in Fig. 7, Fig. 8, and Fig. 9.

TABLE IV. PERFORMANCE COMPARISON OF THE PROPOSED METHOD USING REPRESENTATIVE MACHINE LEARNING ALGORITHMS ON GSE121248

Performance Measure	Reduction Method	Machine Learning Algorithm				
		SVM	NB	RF	KNN	C5.0
Accuracy	SVD full	1	0,94	1	0,78	0,98
	SVD k=10	1	0,96	1	0,95	0,98
	PCA	1	0,91	1	0,92	0,97
	no-FS	1	0,953	1	0,907	0,991
Sensitivity	SVD full	1	0,95	1	0,97	0,97
	SVD k=10	1	0,97	1	0,97	0,97
	PCA	1	0,84	1	0,97	0,92
	No-FS	1	0,973	1	0,973	0,973
Specificity	SVD full	1	0,94	1	0,89	0,99
	SVD k=10	1	0,96	1	0,94	0,99
	PCA	1	0,94	1	0,89	1
	No-FS	1	0,943	1	0,871	1
AUC	SVD full	1	0,945	1	0,73	0,98
	SVD k=10	1	0,965	1	0,955	0,98
	PCA	1	0,89	1	0,93	0,96
	No-FS	1	0,963	1	0,939	0,982

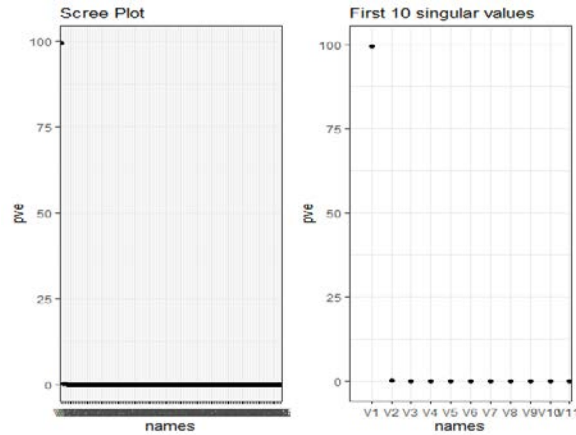

Fig. 4. Eigen Value with *K*-Rank = 10 of SVD Decomposition on GSE550922 and GSE121248.

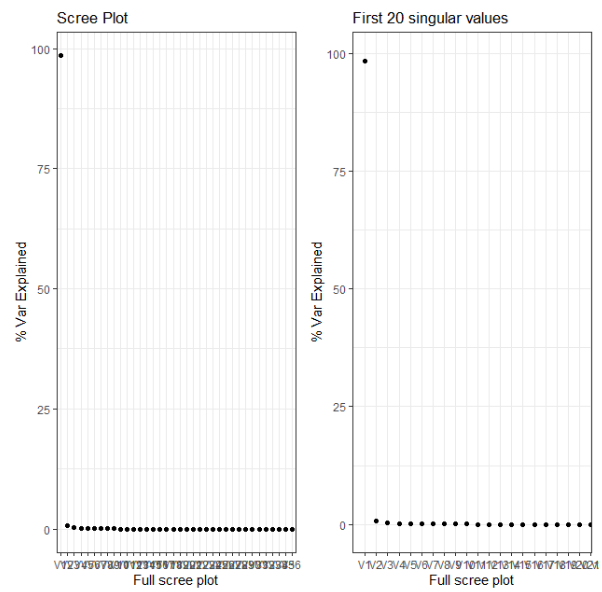

Fig. 5. Eigen Value with *K*-Rank = 20 of SVD Decomposition on GSE114783.

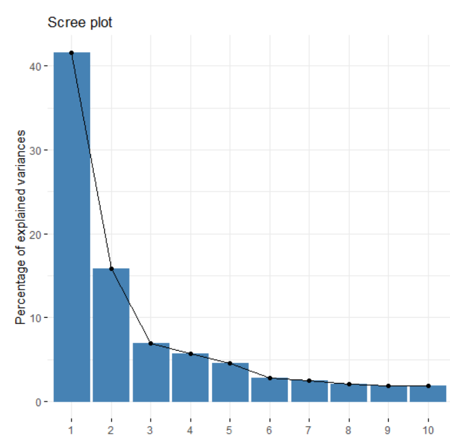

Fig. 6. The Proportion of Variance Explained for each Principal Component in Feature Reduction GSE114873

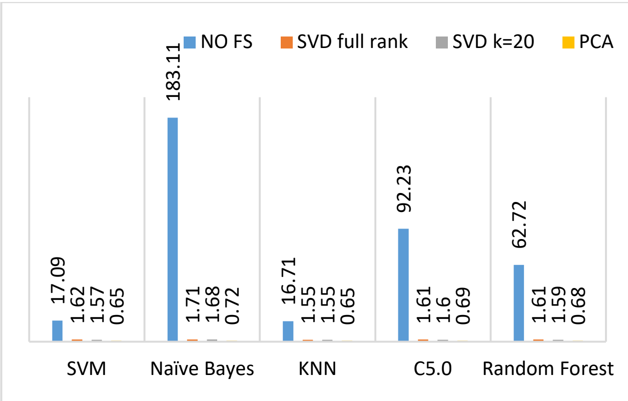

Fig. 7. Comparison of Time Computation GSE114783 using non-Negative Matrix Factorization (NMF-) Dimension Reduction.

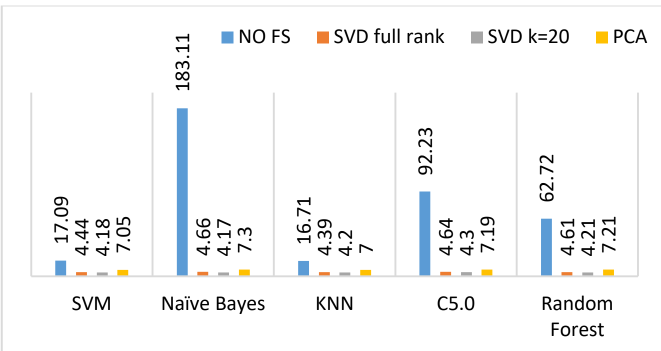

Fig. 8. Comparison of Time Computation GSE55092 using non-Negative Matrix Factorization (NMF-) Dimension Reduction.

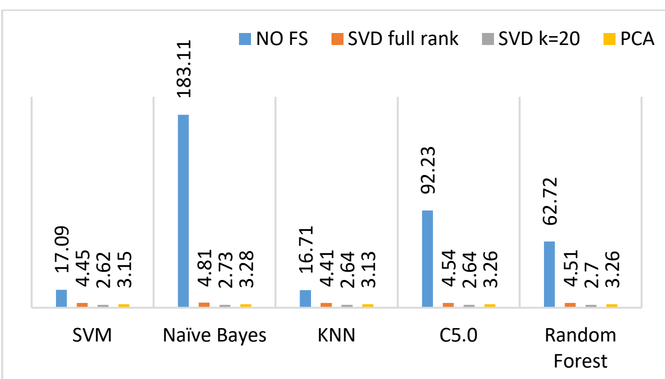

Fig. 9. Comparison of Time Computation GSE121248 using non-Negative Matrix Factorization (NMF-) Dimension Reduction.

V. Conclusion

In this research, feature extraction of the gene expression was applied to reduce high dimensional data using non-negative matrix factorization. Decomposing the data is addressed to get the significant information from the data collection. A unitary matrix consists of singular value with *k*-rank and is produced from decomposition non-negative matrix factorization. The *k-rank* is representative of the number of patterns from value data collection. The maximum dimensional data size after decomposition is the amount of data. Therefore, the proposed method applied unitary matrix from singular vector decomposition (SVD) and Principal Component Analysis (PCA) as data representative to build a classifier model for detection.

The experimental result showed that the reduced data was implemented to the representative supervised learning algorithms for detection and achieved high performance in time and space complexity. The accuracy, sensitivity, and specificity rates are very high, especially for SVM and Random Forest method of 100%. Furthermore, the computation time is very short including decomposing process.

VI. Future Work

A unitary matrix of gene expression data decomposition has k-rank value that indicates the number of patterns in data collection. However, the k-rank is not fixed value for all data set, but it is determined based on eigenvalue convergence. Therefore, it needs to develop method to get the optimum k value.

Acknowledgment

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Anti-Islamic Arabic Text Categorization using Text Mining and Sentiment Analysis Techniques

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Abstract*—The aim of this research is to detect and classify websites based on their content if it encourages spreading hate speech toward Islam and Muslims, or Islamophobia using sentiment analysis and web text mining techniques. In this research, a large dataset corpus has been collected, to identify and classify anti-Islamic online contents. Our target is to automatically detect the content of those websites that are hostile to Islam and transmitting extremist ideas against it. The main purpose is to reduce the spread of those webpages that give the wrong idea about Islam. The proper dataset is collected from different sources, and the two datasets for the Arabic language (balanced and unbalanced) have been produced. The framework of the proposed approach has been described. The approach used in this framework is based on supervised Machine Learning (ML) approach using Support Vector Machines (SVM) and Multinomial Naive Bayes (MNB) models as classifiers, and Term Frequency-Inverse Document Frequency (TF-IDF) as feature extraction. Different experiments including word level and tri-gram level on the two datasets have been conducted, and compared the obtained results. The experimental results shows that the supervised ML approach using word level is the finest approach for both datasets that produce high accuracy with 97% applied on the balanced Arabic dataset using SVM algorithm with TF-IDF as feature extraction. Finally, an interactive web-application prototype has been developed and built in order to detect and classify toxic language such as anti-Islamic online text-contents.

***Keywords*—Web Text mining; text classification; Arabic computational linguistics; natural language processing; SVM; MNB; opinion mining; hate speech; toxic language detection**

I. Introduction and Background

Islamophobia has escalated in the past decades and this has shown in the real world as well as on online websites. This problem has affected Muslim communities especially those living in non-Muslim foreign countries, or any places containing extremists with anti-Islam ideas. Nowadays, it moved to the Internet where webpages are created specifically to attack the Muslim faith. This problem needs to be addressed and solved immediately. Unfortunately, there is a lack of research that addresses and solves the problems of classification in Arabic language, especially the classification of this type of texts. Therefore, this motivates us to search and explore methods and techniques to deal with this issue. Furthermore, the only paper found which is directly related to the work is the one proposed by Vidgen and Yasseri [1] who build a multi-class classifier for detecting islamophobia hate speech based on Twitter dataset; whereas the objective is to consider formal web contents. Moreover, the authors worked only with English content and not the Arabic content; whereas our objective concerns both Arabic language undertaken in this paper and English language conducted in our previous paper [2].

For these reasons, the need to detect anti-Islamic online content has increased, to prevent people from posting inaccurate or incorrect articles and rumors about Islam in order to prevent any attacks against Islam and Muslims. Such study became even more urgent after the mass killing that took place at the Al-Noor Mosque in New Zealand[1], and other unfortunate events such as the killing of Muslim students in America [3].

Therefore, the aim is to build an anti-Islamic related content analysis framework that classifies the content of webpages into anti-Islamic or not anti-Islamic classes. The main aim is to reduce the spread of those webpages that give the wrong idea about Islam. A framework to classify the content is needed in order to prevent these types of events in the future and stop the spreading of extremist ideas about the Muslim religion.

We focus on the accuracy of the classification, not the speed. Therefore, the effectiveness of the proposed approaches that is looking for lies in the correctness of the detection rather than the rapidity of detection. Moreover, the focus was on the formal language in the process of collecting the datasets instead of the informal language. Accordingly, for the Arabic datasets, the collected text was written in Modern Standard Arabic (MSA), which is the formal language instead of the Arabic dialects that are informal. The particular reason for choosing these types of writing texts is because they are more widespread on the web, and easier to process them uniformly.

The remainder of this paper is structured as follows: section two provides a review of some related work. Section three describes the proposed framework along with the data collection and the various stages of the methodology. In section four the implementation is provided. Section five contains experimental results and discussion followed by section six which illustrates the prototype of the proposed web-application. Finally, section seven concludes the paper with a summary and future work.

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A. Web Text Mining

Web text mining enables the extraction and the integration of meaningful information from natural language text that exists in different webpages to be used by data mining algorithms [4]. The information can be discovered from distributed and heterogeneous environments. There are different heterogeneous forms for the information: structured information such as databases, unstructured information such as text files and semi-structured information such as XML documents.

Text mining uses various algorithms to convert unstructured text into structured data, so that it can be analyzed. Web text mining is a very useful process as it reduces the effort and time to extract only the meaningful information from large text data sources. Text mining uses Natural Language Processing (NLP) to analyze and understand the meaning of the text content to perform the required task. Text mining has different tasks including text classification, sentiment analysis and other methods such as text summarization and named-entity recognition.

B. Text Classification and Sentiment Analysis

Text classification is the process of classifying a text into binary classes or multi-classes based on different algorithms. Most of the classification systems go into almost four main phases as shown in Fig. 1: preprocessing, feature extraction, classification and evaluation. Preprocessing of the document includes tokenization, stop-words removal, special symbol removal and other preprocessing techniques such as changing all the words in the text to lowercase and replacing the regular expressions. Preprocessing can help in reducing the dataset dimensionality which eventually reduces the time and memory complexity [5].

When dealing with unstructured text, the text must convert into a structured feature to be used in mathematical modeling; and here comes the role of feature extraction. Feature extraction is the process of converting the unstructured text in the dataset into structured features that can be used by the classifier using either word embedding or weighted word technique. There are some common feature extraction techniques such as: Term Frequency-Inverse Document Frequency (TF-IDF), Term Frequency (TF), N-gram, bag of words, Word2Vec, and Global Vectors for Word Representation (GloVe).

Classification phase is considered the most important phase in text classification where the model learns from the training dataset, therefore, the classifier should be chosen carefully. The final phase consists of evaluating the performance of the model using one of the various measures. There are different methods for evaluating the model such as accuracy calculation, F1 Score and Matthews Correlation Coefficient (MCC) [5].

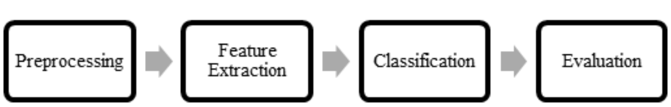

Fig. 1. Text Classification Phases.

Sentiment analysis, also called opinion mining, is an essential and special task associated with text classification where it classifies the text based on the sentimental polarities of the opinions contained in the text.

C. Arabic Computational Linguistics

Arabic language is widely used on the Internet and it is considered the fourth most used language after English, Chinese and Spanish according to the Internet World Stats[2]. Unfortunately, there is a lack of Arabic sentiment resources [6]. Arabic Sentiment Analysis (ASA) is considered a difficult task as it deals with unstructured text including a lot of rhetorical characteristics and implicit meanings, and classifies it as positive or negative documents.

The morphology of the Arabic language is difficult and different from other languages as it starts from right to left, also it does not contain uppercase or lowercase letters. Moreover, the meaning of the word depends on its position in the sentence. Arabic text can be classified into binary classes or multi-classes with the help of NLP to understand the meaning of Arabic text.

Arabic language is a challenging language and it requires good preprocessing techniques to achieve high accuracy. There are different good preprocessing techniques, but the most important ones are stop-words removals, lemmatization and stemming. Furthermore, Arabic language is a rich language that contains a large number of stop-words, where removing them can help to speed the analyses process.

Arabic language also contains many synonyms for the same word that gives the same meaning. Therefore, it is good to use lemmatization and stemming when working with Arabic text to achieve a good accuracy. Moreover, this may require some further preprocessing such as part of speech (POS) tagging, semantic analysis and subjective analysis [7]. Take in consideration that some opinions are expressed using either MSA which is the formal language, or Arabic dialects which are the informal language used in social media, or a combination of both; when preparing the data for analysis [8].

Some issues that ASA faces are in the linguistic and the contextual levels. In the linguistics level, the diacritic marks cause problems. The particular reason for this is that most of the words do not include them, besides the difficulty of the Arabic language morphology. In the contextual level, some negation words appear in the sentence which causes inaccurate results in word polarity. Moreover, some words appear in a domain that changes the polarity depending on the domain in which they are. In addition, some opinions are expressed in a sarcastic way, which causes inaccuracies in the polarity of the word [9].

D. Anti-Islam, Anti-Muslims and Islamophobia

Anti-Islam and anti-Muslims can be expressed as the hatred toward the Islam and Muslims, especially as a political force that promotes terrorism. In particular, it is a criticism of Islam, its actions, its nature, and what it teaches people [10]. Anti-Islam may involve Islamophobia, which is the fear and hatred against the Islamic religion and Muslims.

[2] https://www.internetworldstats.com/stats7.htm

The term Islamophobia has existed around the late 1980s and the early 1990s started in the United Kingdom to express the rejection against the Muslims who live in the West [11]. Some people want to harm and weaken the Islamic religion; therefore, they spread different content that contains wrong information to create confusion and a phobia against the Muslim faith. Some content can contain threatening, blaming, and labelling, which is known as toxic language. Some users write this toxic content without realizing its consequences. Unfortunately, some people label Muslims and Islam based on what they see or hear from the news, people or social media, even if this toxic content is considered as fake news and hate speech, and it has nothing to do with the Islamic teaching.

II. Related Work

A. Arabic Fake News Detection

Detection of Arabic fake news is considered a rough task as the Arabic sentiment resources are limited as well as the corpora and lexicon of Arabic language. Therefore, some researchers [6], [7], [8], [9], [12] and [13] have spent some time trying to solve these issues and implement fake news detection for Arabic texts. Alkhair et al. [12] classified Arabic YouTube comments into rumor and not-rumor. They use YouTube API to collect their dataset which consist of more than 4000 Arabic comments. They built three supervised machine learning algorithms for classification, namely SVM, MNB and Decision Trees. The accuracy of their systems differs according to the topic and the used classifier.

Almerekhi and Elsayed [6] were mainly interested in classifying the Arabic tweets as either automated or manual. They proposed four categories of features: the first category is the formality features where it measures how formal a tweet is based on the emotion, diacritics and elongation. The second category is structural features where it considers the structure of the tweet such as the length of the tweet in terms of the total number of characters, the number of question marks, and the number of exclamation marks. The third category is tweet-specific features where it checks for the data associated with tweets such as retweets, replies, hashtags and URLs contained in the tweets. The last category is temporal features where it focuses on the posting nature such as the activity period on Twitter that checks the time period the account is being used and spreads out the velocity. The dataset was collected from Twitter and consists of 3500 randomly labeled Arabic tweets that contain different dialects including Egyptian, Gulf and other different Arabic dialects. The model has an accuracy up to 92% and has classified 2000 automated Arabic tweets and 1500 manual tweets which shows that most of the Arabic tweets are automatically generated.

Moreover, Penuela [7] has worked on Arabic tweets as well as news headlines. The proposed system uses ML algorithms to classify the Arabic tweets and news headlines into true or deceptive messages. The author used two datasets, the first one consists of 1444 news headlines, 679 of them were true news and 765 are false news; and the second dataset consists of 532 Twitter messages, 259 of them were true tweets and 273 are false tweets. He also used hashtags, user mentions, emojis for the features in Twitter data along with the number of words in the document. Data frame used was for both datasets that contain the bag of words to train the classifier. The obtained results of the F-score of the News and Twitter datasets are 0.70 and 0.77, respectively.

Jardaneh et al. [8] presented a supervised ML model for classifying Arabic tweets based on the credibility of the tweet containing only honest, high-quality news and information. The authors extracted 45 features for each tweet and categorized them into two categories which are content-based features with 26 features extracted from the content and user-based features which are extracted from the profiles of users. The dataset is taken from publicly available dataset named Arabic Corpora for Credibility Analysis that consists of 1862 tweets about the Syrian crisis; divided into two classes: 1051 credible tweets and 810 non-credible tweets and some tweets are excluded because they became unavailable. They used four supervised ML algorithms to compare between them and work with the one that gives the best results; these algorithms are Random Forest, Decision Tree, AdaBoost, and Logistic Regression. The results showed that their system can classify non-credible tweets with an accuracy of 76%.

Bouchlaghem et al. [9] focused on sentiment analysis for MSA on a dataset consisting of Twitter posts. They used several sentiment features including lexicon features, linguistic features and sentence specific features. In addition, they used Tweet specific features as in papers [6] and [7]. They present different supervised ML algorithms for classification including SVM, k-Nearest Neighbor (k-NN), Naive Bayes, Decision Trees, Random Forest. The experimental results showed that the SVM algorithm has a better F-score with 70.64% for classifying Arabic sentiments in Twitter. The second classifier that has an F-score close to the SVM is the Naive Bayes with 70.02%.

Nagoudi et al. [13] implemented two detection methods, the first one for manipulated text detection and the second one for fake news detection. In manipulated text detection, they used two datasets: Arabic Treebank and A New Large-Scale Arabic News Dataset (AraNews) which they collected from different topics and sources. They proposed a method for automatic manipulation of texts and applied it on the AraNews dataset to produce a dataset of manipulated Arabic news. In fake news detection, they used external human-crafted fake news dataset which is a public dataset. They used crowdsourcing to determine the true and the false claims from the title. The experimental results showed that the detection of the manipulated Arabic news achieved good results on Arabic fake news detection where the F-score reached up to 70.06%.

B. Arabic Hate Speech Detection

Faris et al. [14] proposed a deep learning approach to detect and classify hate speech in the Arabic region. Their dataset consists of 3696 tweets without any duplicates and removed any irrelevant tweet. The content of the tweets is related to hate expressions in different topics in the Arabic region. Their approach is based on a word embedding features with a hybrid model of convolutional neural network (CNN) and long short-term memory (LSTM) network. For the preprocessing stage, they have deleted all the non-Arabic characters and stop-words, punctuation, hashtags, numbers, symbols, web addresses and diacritics. Moreover, they have tokenized the Arabic words and also implemented some of the Arabic normalization techniques such as converting any variant of the Arabic Alif letter إ or أ or آinto ا and any ي into ى. For text vectorization, they have used the Word2Vec word embedding model. Their approach classifies tweets as Hate or Normal in terms of accuracy, precision, recall, and F1 measure. The experimental results showed that the AraVec word embedding approach with the recurrent convolutional networks produced good results with 66.564% accuracy.

Omar et al. [15] proposed a standard Arabic dataset that can be used for hate speech and abuse detection. The dataset was collected from more than one platform including Facebook, Twitter, Instagram, and YouTube. The dataset contains 20,000 posts or comments that were labeled manually by three Arabic annotators into two balanced classes, which are hate and not hate labels. Their preprocessing techniques include removing non-Arabic characters, emoji, or URLs, and additionally removing text containing less than two words because it is not necessary and it increases the dataset size. They have tested the dataset performance using twelve machine learning algorithms including MultinomialNB, LinearSVC, LogisticRegression and Decision Tree, in addition to two deep learning architectures namely the CNN, and the RNN. Their experimental results showed that the Complement NB produced the best result compared to the other ML algorithms with accuracy up to 97.59%, while the accuracy for the deep learning algorithm is 98.70% achieved by RNN which make it the highest performance achieved in both machine learning and deep learning.

Husain [16] proposed two approaches; one is based on the ML approach, and the second one is based on the ensemble ML approach, to detect and classify the offensive Arabic language. The ensemble ML classifier combines the prediction of different ML models in order to produce better performance. He has used three models called bagging, random forest, and AdaBoost. He used different preprocessing techniques including converting the emojis to written text in English language then translating it into the Arabic language, and removed the emoji. In addition, he has normalized some of the Arabic dialects and some of the Arabic letters. Furthermore, he removed numbers, symbols, HTML tags and double spaces. For the feature extraction, he used the TF-IDF on the n-gram of 1-2 words and 2-5 characters. The experimental results showed that for the ML models, the SVM produces the highest F1 score results with 82%; after that comes the logistic regression with 81%. For the ensemble ML models, the bagging produces the highest F1 score results with 88%.

Omar et al. [17] proposed a multi-labeled short Arabic text to classify the content into eleven balanced classes including politics, economics, religion and sports. They have found a relationship between hate speech and the different topics in social media; most of the hate speech is shown in the political posts, followed by sports and some of the economic posts. Their dataset consists of 44000 posts and tweets collected from Facebook and Twitter containing eleven topics. They used common preprocessing techniques such as tokenizing, stemming, removing URL and emojis, in addition to removing the diacritics, Tatweel and removing characters that appear more than one time. For the feature extraction, they have used three techniques N-gram, bag of words and TF-IDF with nine ML algorithms including MultinomialNB, LinearSVC, LogisticRegression and Decision Tree to evaluate the classifier with the best performance. The classifier with the best performance was the LinearSVC classifier with N-gram (1, 2) with accuracy score of 97,92%. Moreover, they have built a dataset for Arabic vulgar speech consisting of 6,000 posts; each comment is manually labeled as hate or non-hate speech.

Vidgen and Yasseri [1] proposed a multi-class classifier to detect and classify Islamophobic text on social media where it classifies the document into weak Islamophobic, strong Islamophobic and non-Islamophobic content. They have collected manually their dataset, which consists of 140 million tweets taken from Twitter. The used input feature is a gloVe word embeddings model that is trained on their collected dataset; they did not mention anything about the used preprocessing techniques. They have tested the model on six different algorithms namely Naïve-Bayes, Random Forests, Logistic Regression, Decision Trees, SVM and Deep Learning. All the algorithms produced good results ranging from 61.23% to 72.17%, but the best was achieved by SVM with 72.17% followed by Deep Learning with 71.14%. For the classification, they have used cross-validation on the SVM model. The model achieved good results with 77.6% accuracy score and 83% balanced accuracy score.

III. PROPOSED FRAMEWORK

The framework of the proposed methodology consists of four stages as shown in Fig. 2.

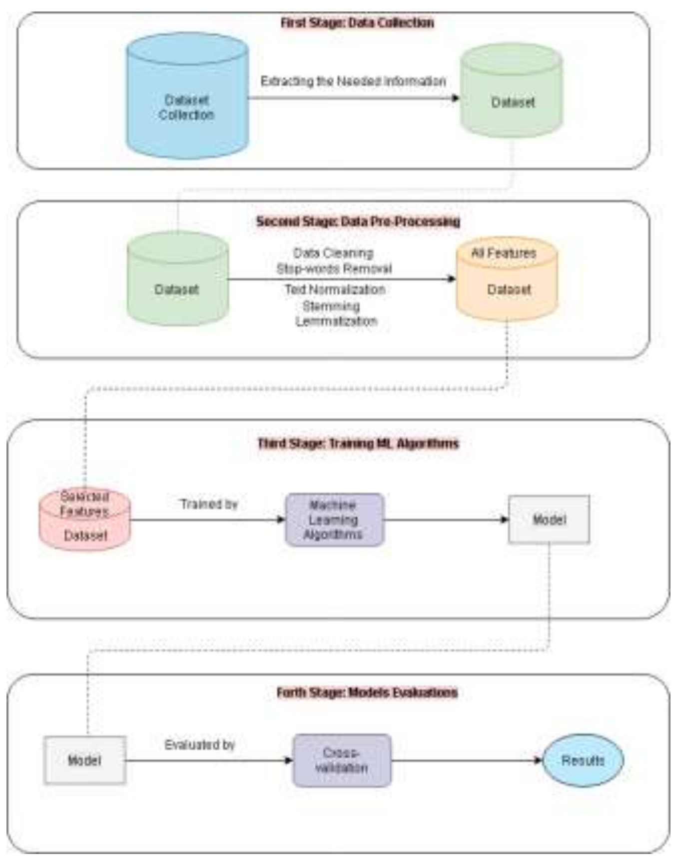

Fig. 2. Framework of the Proposed Approach.

The first stage consists of data collection, where the data is collected from different Arabic sources into two different datasets, each dataset contains an anti-Islam text content and a not anti-Islam text content. The second stage involves data pre-processing, where the data is prepared for processing and selects the features to be used in the next stage. The third stage is the process of training the ML models, where the ML algorithm is provided with the training data to learn from. The last stage is the evaluation of the ML models. The models used in this research are based on a supervised ML approach using SVM and MNB algorithms.

A. Data Collection and Annotations

The ambition is to create a general benchmark dataset containing a huge dataset for anti-Islamic web text content. The collected data were from articles, journals and some of them are from personal blogs. The main reason for choosing these types of data is because the focus was in the formal language used in the academic writing content and not informal language used in social media. The data was gathered from the Internet using Yahoo and Google search engines. Furthermore, the MSA text content was gathered, which is the formal Arabic language instead of the informal Arabic dialects. The collection of the Arabic data started from the end of February 2021 until the mid of April 2021.

The main keywords used to collect data in Arabic language were: معاداة الإسلام، مناهضة الإسلام، الإساءة للرسول، كره الإسلام، محاربة الإسلام، الإنفصالية الإسلاموية، اضطهاد المرأة، الشمولية الإسلاموية والتطرف الإسلاموي.

These keywords helped us to reduce the amount of search, in order to find the desired content, due to the huge number of articles that talk about Islam in good or in bad ways. Two datasets for the Arabic language were produced.

The collected data is organized into an excel spreadsheet using a web-scraping tool called Octoparse. This tool takes the URL of the webpage to extract data from, then selects the target data to be extracted, and runs the scraping to get the data as CSV, Excel, Application Programming Interface (API), or save them to a database. The extracted data contain the title, the content, the URL, the date, and label them as an anti-Islamic content or not. During the process of collecting data, one challenge was the extraction and the retrieval of the blocked webpages containing extremist ideas or false information about Islam from Saudi Arabia search engines.

B. Data Preprocessing

Preprocessing is considered an important stage in the process of preparing the data to be used. This stage includes different techniques such as stop-words removal, normalization, stemming and lemmatization.

Stop-words are a list of the most used words in a language. This list is different for different languages and there are different public stop-word lists that can be used in NLP. Stop-words can be safely removed without changing the meaning of the text. In English language, some stop-words are: the, is, in, on, at, which, and of …, whereas in Arabic language some stop-words are: الذي، إن، أنا، أنت، أنتم and إلى.

Text normalization includes different techniques to end up with a clean corpus that can be used in the classification process. If the text contains numbers, there are different ways to deal with them; either keep them as they are, or remove them using regular expressions, or convert them into words that can be used. Normalization also includes removing punctuations and white spaces, which are the starting and the ending spaces in the text. Furthermore, tokenization is the good way to normalize the text, which is the process of dividing the text into smaller parts known as a token.

Stemming removes the last characters (suffixes) and/or the beginning characters (prefixes) in the word to return the word into its stem or root. This process can lead to incorrect words in the language. This technique is one of the most useful and effective techniques in NLP. Stemming is used in the classification task to reduce the high dimensionality of the document and increase the functioning of the classifier especially in difficult languages such as Arabic language. Some of the Arabic stemming are: Information Science Research Institute Stemmer (ISRI Stemmer), and Arabic light Stemmer (ARLSTem) (both are included in NLTK library).

Lemmatization groups together the inflected forms of the word to be analyzed as a single element, specified by the lemma or the dictionary form of the word. This technique produces more accurate results than stemming technique. The meaning of the text is preserved as it takes into account the context of the words. However, using this technique requires lots of computation and deep knowledge about the morphology of the language.

C. Feature Selection and Classification Process

Feature extraction enables us to convert unstructured text into a structured feature, so that it can be used in the classification process, which requires mathematical modeling for working.

Classification process is considered a critical step in building the right model in text classification where the text can be automatically classified into one or more defined categories. There are different algorithms that can be used in this step but to obtain good results, the size of the dataset should be taken into consideration. If the dataset is large it is best to use deep learning, but if the dataset size is relatively small it is better to use ML algorithms.

One of the most used and accurate ML algorithms is SVM. SVM is one of several supervised learning algorithms used in text classification; the algorithm classifies a given document based on some selected features into one of the pre-labeled categories. The reason for choosing this algorithm is because the dataset consists of almost 9000 data, that is relatively small and hence this algorithm is the most appropriate for this situation. In addition, it needs less data for training the model, which is suitable for the dataset to produce accurate and fast results.

Naive Bayes classifier is also a supervised ML algorithm used for classification; the algorithm uses Bayes' theorem where it computes the conditional probabilities of the occurrence of two events based on the probabilities of each individual event. Naive Bayes has different members such as

Gaussian, Bernoulli and Multinomial, and one of the best members that produce good results is MNB. The reason for choosing this algorithm is because it is the second most suitable algorithm for the datasets (as we will prove it later), this algorithm does not require much computation for classification. In addition, this algorithm works well with small to medium datasets, and it produces accurate results.

D. Model Evaluation

In the model evaluation phase, the model is tested on unseen dataset to evaluate how well the ML model works on these new dataset. The performance of the model can be estimated using two techniques: Holdout and Cross-Validation. In holdout evaluation, the dataset is randomly divided into three subsets: training, validation and testing. Training set is a subset of the dataset used to build the model. Validation set is the subset of the dataset used to evaluate the performance of the model. Testing set is an unseen dataset that can be used to test the future performance of the model.

Regarding cross-validation technique, it divides the dataset into a training set to train the model and an independent predefined set used to evaluate the performance of the model. One of the cross-validation techniques is k-fold cross-validation, where the dataset is divided into k equal size such as 5 or 10 folds. This process is repeated k times, where most of the data are used in the test set. Holdout approach is a simple and fast approach, but it has high variability that causes differences in accuracy. However, cross-validation reduces bias and variance because most of the data are used in the test set.

In the model evaluation, there are various metrics that can be used to measure model performance. Some of the classification metrics are: Classification Accuracy, Confusion Matrix, Logarithmic Loss, Area Under the Curve (AUC) and F-measure.

Classification accuracy is the ratio of all the correct predictions done by the model. Confusion matrix shows the true positive and the true negative (correctly predicted as positive and negative), the false positive and the false negative (incorrectly predicted as positive and negative). Logarithmic loss measures the performance of the model as a probability value between 0 and 1, where the optimal model achieves log loss of 0. AUC is used when a binary classifier can differentiate between the two classes, the curve of the optimal result achieved by the classifier will be along the Y axis and then along the X axis. F-measure known as F-score, it measures the accuracy taking into account the precision and the recall of the test to compute the score.

IV. Implementation

A. General Information about the Datasets

The dataset is the core of any classification model to evaluate the performance of the proposed approach. Therefore, two datasets were collected consisting of different numbers of data. The two datasets contain Arabic text (non-balanced and balanced datasets). The balanced Arabic dataset consists of 6142 articles and 1038 words per article on average. The non-balanced Arabic dataset is made up of long articles containing 8510 articles, and 879 words per article on average. The maximum number of words in the longest article is 6605 words in both datasets; and the minimum number of words in the shortest article is one word in both datasets. The maximum number of words in the anti-Islamic articles is 6108, whereas for the non-anti-Islamic articles is 6605.

Fig. 3 illustrates the information given above about the two datasets, and Fig. 4 illustrates the information given above for only the anti-Islamic contents in the datasets.

B. Data Preparation and Preprocessing

After collecting the data that is related to the topic, some preprocessing techniques were performed to keep only the necessary information. Some of the preprocessing techniques are removing punctuation, removing whitespaces and replacing some characters with others such as phone number with the words number. Moreover, the Arabic stop-words are removed. Removing those words in the dataset will produce a smaller dataset which will help in speeding up the process of classifying the documents.

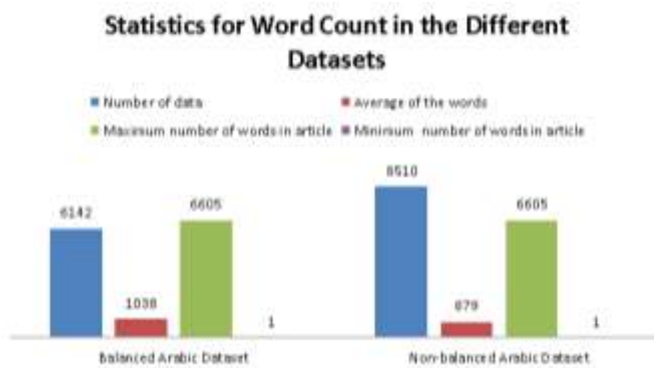

Fig. 3. Statistics about the Two Datasets.

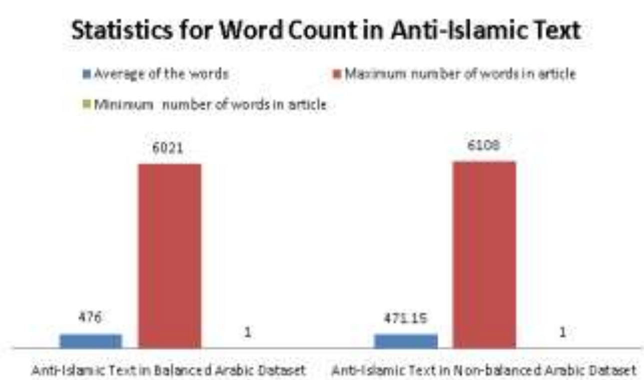

Fig. 4. Statistics about the Anti-Islamic Contents in the Datasets.

Fig. 5 illustrates a sample of the Arabic dataset before the preprocessing phase.

	ID	Title	Content	Link	Date	Labels	Label
0	1	[illegible]	[illegible]	https://www.[illegible]	NaN	1	Ant
1	2	[illegible]	[illegible]	https://www.[illegible]	NaN	1	Ant
2	3	[illegible]	[illegible]	https://www.[illegible]	NaN	1	Ant
3	4	[illegible]	[illegible]	https://www.[illegible]	NaN	1	Ant
4	5	[illegible]	[illegible]	https://www.[illegible]	NaN	1	Ant

Fig. 5. Arabic Dataset before the Preprocessing Phase.

Furthermore, Arabic stemming is used which return the Arabic words into their root based on some Arabic language rules. However, in some words, when the suffixes and/or the prefixes are removed, the result can produce a word that is not in fact a word in the Arabic language.

For the Arabic language stemming, the ISRI Stemmer is used, which is a rule-based stemmer that stems the word based on some rules to return the word to its root [18].

Fig. 6 shows some preprocessing techniques used to handle the Arabic language text. These techniques include removing Tatweel or Kasheeda, which refers to the elongation character "ـ" so as to create justification in Arabic language; removing diacritics which are the Harakat, that represent the short vowel marks in Arabic language, the small letters, and the Tashkeel which are the supplementary diacritics used as phonetic guides marks in Arabic language. Moreover, the Arabic punctuations are removed.

```
text = strip_tashkeel(text)
text = strip_diacritics(text)
text = strip_tatweel(text)
```

Fig. 6. Some Arabic Preprocessing Techniques.

C. Feature Selection

We have used TF-IDF with word level, where it is considered the frequency of a single word in the dataset. Moreover, the TF-IDF with N-gram is used, which is a model that depends on the sequence of words with a predefined length N to predict the next word. In the experiment, the tri-gram word-based model is used, where it is considered the frequency of three words in the dataset.

D. Training Process

The non-balanced Arabic dataset was tested on six different algorithms based on the different related work we discussed previously, in order to select the best two classifiers that produce good results based on the dataset. The different classification algorithms we have tested are: Decision Tree, k-NN, Random Forest, Logistic Regression, MNB and SVM classifiers.

Table I shows that the six different algorithms produce good results except the k-NN; with accuracy ranging from 90.601% to 97.274%. However, the SVM classifier outperforms the other five classifiers followed by the MNB classifier. The accuracy of SVM is the highest with 97.274% while the MNB accuracy is 96.193%, which is less than the SVM classifier by 1.081 points.

Due to the results of the above comparison between the six different classification algorithms, the SVM and the MNB algorithms are selected to be used for defining the ML model in order to achieve the goal in detecting and classifying the anti-Islamic content.

The dataset is divided into training and testing sets. The training data is used to train the models. In addition, we used the testing data to make sure that the trained model performs well for the hidden data. The data is split into 70% for training data and 30% for testing data used in the end when the training of the model is completed.

TABLE I. TESTING THE DIFFERENT CLASSIFIERS

Algorithm	Accuracy
k-NN classifier	64.661%
Decision Tree classifier	90.601%
Random Forest classifier	92.105%
Logistic Regression classifier	95.864%
MNB classifier	96.193%
SVM classifier	97.274%

E. Overcoming the Problems of Data Leakage and Harm

We used TF-IDF after splitting the datasets into training and testing sets, to ensure that no information is shared between the two sets. This is considered as a big problem and it is called data leakage, which means that the data in the training and testing are accidentally shared. To overcome data leakage problems, different techniques are used to minimize it during the process of building the model. These techniques include splitting the datasets into training and testing before using TF-IDF, pipeline architectures, ten folds cross-validation and testing the model using unseen validation dataset.

Another problem arises in these types of classification is that sometimes the classifier can cause harm instead of reducing it during the process of classification [19]. This problem can happen when the text contains racial bias or minority populations; in our case, *women* and *hijab* themes are considered kinds of harm. Moreover, this problem can be caused by different problems in the training data, labels or even the resources used in the model [20]. Unfortunately, there are no general solutions for this problem, but the model can be evaluated on different datasets with different topics [21].

V. RESULT, EVALUATION AND DISCUSSION

A. Tri-gram Level TF-IDF

Table II and Table III list the different results when using the tri-gram for the two classifiers on the two different datasets. The observation can show that the results have no significant change. The difference between the results obtained by the two classifiers is one percent. The accuracy obtained using the MNB classifier is 89% compared to 88% obtained with the SVM classifier.

The experimental results show that for the Arabic language, the highest accuracy is achieved by the ML approach, using MNB on a non-balanced Arabic dataset with tri-gram level TF-IDF as feature extraction, with an accuracy of 89%.

TABLE II. RESULTS FOR TRI-GRAM ON NON-BALANCED DATASET

Non-balanced	*Precision*	*Recall*	*F1 score*	*Accuracy*
TF-IDF with SVM	89%	88%	88%	88%
TF-IDF with MNB	90%	89%	89%	89%

TABLE III. RESULTS FOR TRI-GRAM ON BALANCED DATASET

Balanced	*Precision*	*Recall*	*F1 score*	*Accuracy*
TF-IDF with SVM	87%	87%	87%	87%
TF-IDF with MNB	86%	70%	72%	70%

Table IV and Table V list the precision, the recall and the F1 score for the negative articles on the different datasets. The results show that the overall values of the precision and the F1 score concerning the non-balanced datasets achieve the best results compared to the balanced datasets. However, the recall is higher in the balanced datasets compared to the non-balanced one.

TABLE IV. RESULTS FOR NON-BALANCED NEGATIVE ARTICLES DATASET USING TRI-GRAM

Dataset Type	*Non- balanced*	*Precision*	*Recall*	*F1 score*
Arabic dataset (Negative Articles)	TF-IDF with SVM	93%	89%	91%
	TF-IDF with MNB	96%	88%	92%

TABLE V. RESULTS FOR BALANCED NEGATIVE ARTICLES DATASET USING TRI-GRAM

Dataset Type	*Balanced*	*Precision*	*Recall*	*F1 score*
Arabic dataset (Negative Articles)	TF-IDF with SVM	88%	87%	87%
	TF-IDF with MNB	43%	97%	59%

B. *Word Level TF-IDF*

Fig. 7 shows the confusion matrix using ML model with non-balanced Arabic dataset on word level, whereas Fig. 8 shows the confusion matrix using ML model with non-balanced Arabic dataset on tri-gram level with the same classifier. When TF-IDF is used, the True Positive (TP), which is the number of correct predictions, is 1617 for the ML model on word level with non-balanced Arabic dataset, and on tri-gram level with non-balanced Arabic dataset the number of correct predictions is 1573. For the True Negative (TN), which is the correct predictions for the negative class, the model on word level produces 860, and the model on tri-gram level achieves 717 correct predictions. For the False Positive (FP), the number of predictions in the model on word level is 33, and in the model on tri-gram level is 186. For the False Negative (FN), which is the false prediction of the negative class, the model on word level produces 43, and the model on tri-gram level achieves 113 negative predictions.

Table VI and Table VII list the different results when using the word level for the two classifiers on the two different datasets. The results show that for all the measurements: the precision, the recall, the F1 score and the accuracy are the same for each algorithm. However, the comparisons between the two classifiers (SVM and MNB), on the balanced and a non-balanced Arabic datasets show a small change in results.

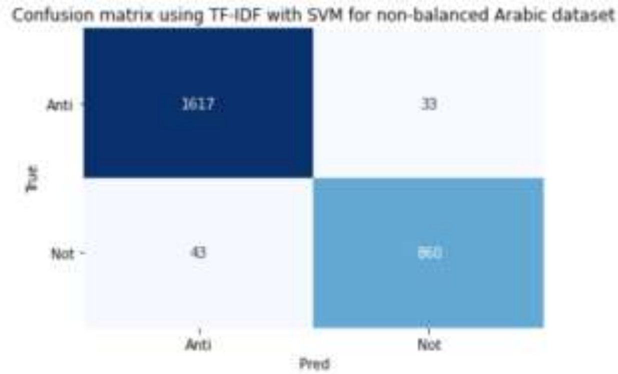

Fig. 7. Confusion Matrix using Word Level TF-IDF with SVM for Non-Balanced Arabic Dataset.

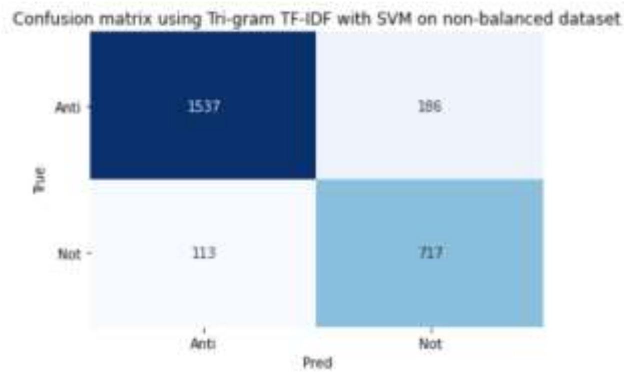

Fig. 8. Confusion Matrix using Tri-Gram Level TF-IDF with SVM for Non-Balanced Arabic Dataset.

TABLE VI. RESULTS FOR WORD LEVEL ON NON-BALANCED DATASET

Non- balanced	*Precision*	*Recall*	*F1 score*	*Accuracy*
TF-IDF with SVM	97%	97%	97%	97%
TF-IDF with MNB	95%	95%	95%	95%

TABLE VII. RESULTS FOR WORD LEVEL ON BALANCED DATASET

Balanced	*Precision*	*Recall*	*F1 score*	*Accuracy*
TF-IDF with SVM	97%	97%	97%	97%
TF-IDF with MNB	83%	75%	73%	75%

Table VIII and Table IX list the precision, the recall and the F1 score for the negative articles on the different datasets using word level. The results show that the overall values of the precision, the recall and the F1 score concerning the non-balanced dataset achieve the best results compared to the balanced dataset.

TABLE VIII. RESULTS FOR NON-BALANCED NEGATIVE ARTICLES DATASET USING WORD LEVEL

Non-balanced	*Precision*	*Recall*	*F1 score*
TF-IDF with SVM	97%	98%	98%
TF-IDF with MNB	98%	94%	96%

TABLE IX. RESULTS FOR BALANCED NEGATIVE ARTICLES DATASET USING WORD LEVEL

Balanced	*Precision*	*Recall*	*F1 score*
TF-IDF with SVM	96%	97%	97%
TF-IDF with MNB	100%	51%	67%

C. Discussion

A detailed description is given about all the experimental results applied to the datasets and achieved by the proposed two classifiers approach using the feature extraction techniques, namely word level TF-IDF and Tri-gram level TF-IDF.

The experimental results using our approach with different datasets (Arabic balanced and Arabic non-balanced), showed that the best algorithm producing high accuracy was SVM with word level TF-IDF as feature extraction. Therefore, almost there is no matter regarding if the datasets are balanced or not except for the tri-gram on a non-balanced dataset.

In addition, the results demonstrated that the SVM was the best classifier in terms of accuracy, and it outperforms the MNB classifier in almost all experiments.

VI. WEB-APPLICATION PROTOTYPE

We have developed and built an interactive web-application prototype using the Streamlit framework in python. In the homepage of the web application (Fig. 9), you can choose between the two proposed datasets. Furthermore, there are two proposed classifier models (SVM or MNB) to choose from. In addition, you also have the ability to choose at the N-gram level (word level or tri-gram level), in order to finally test and predict the category of the entered text if it contains an anti-Islamic content or not.

Fig. 10 illustrates an example of a classification process result. The LIME library is used to explain predictions of a given text. LimeTextExplainer helps in explaining the predictions of a trained model to categorize sentences on any given area. Fig. 10 below shows the result of the entered text as not anti-Islamic content associated with their probability, followed by the LIME explanation.

Fig. 9. Web-Application Homepage.

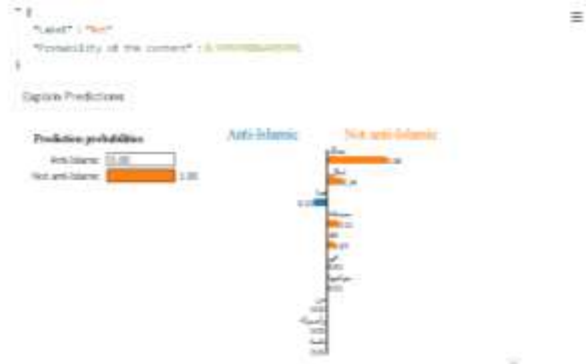

Fig. 10. Results of the Classification Process.

VII. CONCLUSION AND FUTURE WORK

We have proposed an anti-Islamic Arabic text categorization framework using text mining and sentiment analysis techniques. This framework will help us to identify and classify the text content of different webpages into anti-Islamic content or not anti-Islamic content; and to increase awareness toward these kinds of toxic contents that promote hate. Proper datasets have been collected and used in this framework to classify the anti-Islamic web text content; also, the features that can be used for anti-Islamic toxic language texts have been identified.

The models used in this research are based on supervised ML approaches using SVM and MNB algorithms. The experimental results showed that for the datasets, the best algorithm that produced high accuracy with 97% applied on the balanced Arabic dataset using SVM algorithm with word level TF-IDF as feature extraction. In addition, the results demonstrated that the SVM was the best classifier in terms of accuracy, and it outperforms the MNB classifier in almost all experiments.

We have faced different challenges during the process of achieving our goals such as the absence of a dataset that contains anti-Islamic content in Arabic. In addition, a number of webpages that promote hate or spread false information about Islam were blocked, and we were not able to reach them from Saudi Arabia. This slowed down the process of collecting and gathering the data and made it harder to find different webpages that contain this kind of information. Another encountered issue faced in this research was the lack of an efficient Arabic preprocessing library that supports us to accomplish some tasks such as lemmatization.

In the future, more data will be added to the datasets in order to explore the use of a deep learning approach. We propose to implement a translation-based approach to deal with different languages other than Arabic in order to overcome the lack of datasets in the respective language. Furthermore, the ontology will be taken into account to encode the knowledge in this domain into a graph in order to improve the accuracy of the classification. Another research area is to explore different social media contents on which can be collected and accumulate data, to deal with the Arabic dialects, which are informal languages; and compare their contents with the MSA datasets, which contain formal language, and notice what the experiment's results will show.

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Machine Learning Model to Analyze Telemonitoring Dyphosia Factors of Parkinson's Disease

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***Abstract*—For many years, lots of people have been suffering from Parkinson's disease all over the world, and some datasets are generated by recording important PD features for reliable decision-making diagnostics. But a dataset can contain correlated data points and outliers that can affect the dataset's output. In this work, a framework is proposed where the performance of an original dataset is compared to the performance of its reduced version after removing correlated features and outliers. The dataset is collected from UCI Machine Learning Repository, and many machine learning (ML) classifiers are used to evaluate its performance in various categories. The same process is repeated on the reduced dataset, and some improvement in prediction accuracy is noticed. Among ANOVA F-test, RFE, MIFS, and CSFS methods, the Logistic Regression classifier along with RFE-based feature selection technique outperforms all other classifiers. We observed that our improved system demonstrates 82.94% accuracy, 82.74% ROC, 82.9% F-measure, along with 17.46% false positive rate and 17.05% false negative rate, which are better compared to the primary dataset prediction accuracy metric values. Therefore, we hope that this model can be beneficial for physicians to diagnose PD more explicitly.**

Keywords*—Parkinson's disease; correlation; outliers; machine learning; RFE-based analysis

I. Introduction

Parkinson's disease (PD) is a chronic, neurodegenerative disease of the nervous system which affects our body movement including speech [1]. James Parkinson was invented this disease in 1857 and explained its condition as Shaking Palsy [2]. The main reason of PD is actually unknown. It affects 1% of people who are older than 65 years, and no medical treatments can cure this disease completely [3]. Almost 90% patients face trouble speaking normally as well as fail to express facial emotion; it results in slow speaking speed, slur words, mumbling, etc. [4]. The average age of patients lies between 55 to 65 years old [5]. Different environmental factors like rural living, consumption of water, pesticide manage and exposure, environmental toxin create individual's risks of happening PD. Out of many neurodegenerative disease such as Alzheimer's disease, headache disorders, stroke, epilepsy, multiple sclerosis, dementia, PD is considered as the second most common nerudegenerative disorder [2]. Different brain cells contain substantia nigra cells which produce dopamine. Dopamine is a chemical element which transmits signals within brain and controls the movement of body. When 60-80% dopamine creating cells are lost, there are not produced sufficient dopamine and people face about movement disorder that causes PD [6].

To ensure proper treatment about PD, it is required to identify these patients as early as possible. Many works have been happened where PD patients are identified based on different aspects and parameters. The symptoms of PD is divided into motor and non-motor group. The motor group is also called as cardinal symptoms which include tremor, rigidity, postural instability, and slowness of movement. Instead, non-motor group shows the loss of speech, facial expression, and handwriting. These types of symptoms are called dopamine non-responsive symptoms. Speech properties are one of the most effective non motor element because 90% patients are faced PD based on vocal impairment [7]. In addition, non motor symptoms like speech are not decisive where these attributes are employed with cerebrospinal fluid measurement (CSF) and dopamine transporter imaging for predicting PD [8]. Due to redundant points and degradation of speech quality, it is more difficult for physicians to detect PD cases by assessing their vocal records in a manual way. Thus, an automatic model is useful which extracts speech patterns of subjects and detects PD more efficiently.

However, machine learning is a study of computer algorithms where it analyzes existing instances and predict expected outcomes [9], [10]. It is defined as a process of discovering useful, interesting, and complex patterns from a large amount and high dimensional data [11], [12]. Likewise, this technique is useful to predict PD through a set of practical datasets. In this work, we propose a machine learning-based framework to make PD detection convenient for clinicians. This model contains various state-of-art techniques like feature selection, outlier detection, and classification. Then, several evaluation metrics like accuracy, area under curve (AUC), f-measure, g-mean, sensitivity, specificity, fall-out, and miss rate are used to assess the performance of individual classifiers [13]. The performance of classifiers are useful to detect the most significant feature subset where different classifier performs well than other subsets. The main contributions of this proposed PD diagnosis model are mentioned below:

- Various feature subsets are generated and identified the best one by assessing the performance of individual classifiers.
- Detect anomalous/noisy elements to obtain more suitable feature subsets.

- To justify the performance of classifiers, numerous evaluation metrics are considered in this work.

This paper is organized as follows: Section 2 includes details of similar studies and their implications. Section 3 presents the methodology of a machine learning model for detecting PD at early stage. Also, it outlines the description of PD dataset, feature selection, classification and its evaluation metrics. Section 4 shows the experimental results of various classifiers for individual feature subdatasets, compare them to identify best feature subset. Finally, Section 5 concludes by summarizing this work and mentioning future research strategies.

II. Related Work

Numerous works were happened to predict PD at early stage. Das [14] used different classifiers like Artificial Neural Network (ANN), DMneural, Regression, and Decision Tree (DT) to efficiently detect PD and compare their results. Tsana et al. [15] employed novel speech signal processing feature selection and statistical classifiers to investigate PD. Challa et al. [8] developed an automatic PD diagnosis model with feature extraction and various classifiers such as Multilayer Perceptron (MLP), Bayes Net (BN), Random Forest (RF), and boosted LR for early prediction of PD. Shamli et al. [16] proposed a multi-class classification model including C4.5, Support Vector Machine (SVM), and ANN to enhance prediction tendencies as well as reduce the cost for PD. Tong et al. [17] proposed a machine learning framework that achieves a 75% classification accuracy along with 69% balanced accuracy for neurodegenerative disease diagnosis. Since PD is a neurodegenerative disease as well, their system can improve the prediction rate for clinical use. Li et al. [18] proposed a PD-oriented classification algorithm for improved classification performance. It involves a Classification and Regression Tree (CART) approach for picking the optimal training samples iteratively and an ensemble-learning algorithm combining RF, SVM, and ELM. Mathur et al. [19] implemented various classifiers like SMO, KNN, Rf, AdaBoost.MI, Bagging, MLP, and DT to scrutinized PD. Nilashi et al. [5] proposed a hybrid intelligent system for PD prediction where Incremental SVM is utilized to estimate Total-UPDRS and Motor-UPDRS. Almeida et al. [20] used 18 feature extraction and 4 machine learning methods to investigate sustainable phonation and speech tasks. Besides, phonation analysis was more efficient than speech task. Lahmini and Shmuel [21] investigated PD based voice pattern using various pattern ranking methods and optimized SVM. Mostafa et al. [22] proposed a new multiple feature evaluation approach (MFEA) as well as DT, NB, ANN, RF, and SVM show its best results for MFEA. Pham et al. [7] combined voice and image dataset where pairwise correlation and k-means clustering extracts features from vocal dataset. Then, it proposed an ensemble method to predict PD. Pahuja et al. [2] extracted various significant features and selected feature subsets from PD voice input dataset. Then, different classifiers such as ANN, SVM, and KNN were implemented and ANN with levenberg-marquardt algorithm provides the best results. Senturk et al. [6] proposed a machine learning model where feature importance and recursive feature elimination (RFE) methods were implemented for feature selection. Then, CART, ANN, and SVM were used to identify PD patients. Karabayir et al. [23] analyzed PD acoustic data using light and extreme gradient boosting, RF, SVM, KNN, LASSO, and LR. Then, they used feature importance procedure to identify significant features for classifying PD. Lamba et al. [24] represented a speech signal based hybrid PD disease diagnosis system where numerous feature selection (i.e., mutual information gain, extra tree, genetic algorithm) and classification methods (i.e., NB, KNN, RF) were employed. Also, SMOTE method was used to balance PD dataset. Paramanik et al. [25] used two recent decision forest algorithms such as SysFor, ForestPA including RF for developing PD detection models with the optimization of DT.

III. Materials and Methods

In this work, we propose a machine learning framework to improve the efficiency of a PD dataset where the data validity is judged by applying many classifiers. For each classifier, multiple performance parameters are measured where we observed that these results could be improved by removing insignificant features and outliers. In the feature selection process, we employ a total of four methods and notice its outcomes.

A. Parkinson's Disease Data

We collected the dataset from the University of California Irvine (UCI) Machine Learning Repository, approved by the Bioethical Committee from the University of Extremadura. The dataset was created by Naranjo et al. [26]. It contains 240 instances for only 80 people whose ages are greater than 50 years old. Among 40 controls, there are found 22 men and 18 women respectively. On the other hand, 27 men and 13 women are defined as PD patients. According to the mean of Unified Parkinson's Disease Rating Scale (UPDRS), all subjects have 5 years or less PD duration. This dataset contains 44 acoustic features which captures a sustainable vowel /a/ for 5s with three runs. These features include five categories such as pitch local features, amplitude local perturbation, special envelope, noise and nonlinear measures. The individual features of these categories are given as follows:

- **Pitch Local Features:** jitter relative, jitter absolute, jitter relative absolute perturbation (RAP), jitter pitch perturbation quotient (PPQ).
- **Amplitude Perturbation Measures:** shimmer local, shimmer dB, 3 point amplitude perturbation quotient (APQ3), 5 point Amplitude Perturbation Quotient (APQ5), 11 point Amplitude Perturbation Quotient (APQ11).
- **Noise:** Harmonic-to-Noise Ratio (HNR) such as HNR05 [0–500 Hz], HNR15 [0–1500 Hz], HNR25 [0–2500 Hz], HNR35 [0–3500 Hz], HNR38 [0–3800 Hz], Glottalto-Noise Excitation Ratio (GNE).
- **Special Envelope:** 13 Mel Frequency Cepstral Coefficients (MFCCs) and 13 Delta Coefficients.
- **Non Linear Measure:** Recurrence Period Density Entropy (RPDE), Detrended Fluctuation Analysis (DFA), and Pitch Period Density Entropy (PPE).

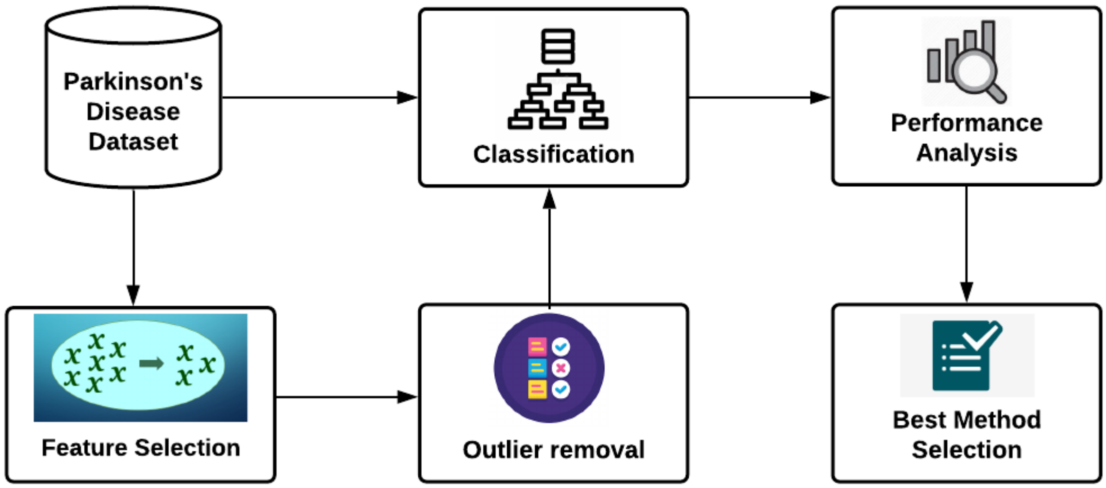

Fig. 1. Pipeline Diagram of the Overall Methodology.

B. Methodology

The he overall implementation are demonstrated in the following Fig. 1:

1) Data Acquisition: After gathering PD voice dataset for UCI data repository, we clean and check missing, wrong, and incomplete information in this dataset. Afterwards, this dataset is prepared for further analysis.

C. Feature Selection Methods

Feature selection methods are useful to reduce the number of input variables and lessen the computational cost of these predictive models. In this work, we apply different feature selection methods into primary dataset and explore several feature subsets. Then, some sub datasets are generated using these subsets.

1) Correlation based Feature Selection (CFS): Correlated values are linearly dependent on each other. Some features don't have any significant impact on the predicted responses, but they have a few drawbacks. A correlation matrix is created to find out the correlation among different features and remove some of them have higher coefficients above a particular limit [27]. It is a square matrix that consists of equal dimensions as features where all the possible correlated pairs are identified and displayed altogether. In order to drop them, a threshold is considered so that all columns exceeding this limit are eliminated. As expected, the number of columns of our dataset is decreased now, and it only contains features having a coefficient less than 0.90.

2) Analysis of Variance (ANOVA) F-test: ANOVA F-test [28] is really helpful to determine if more than one data samples' mean can be driven from the same or different distribution. On the other hand, F-statistic or F-test refers to a class of statistical tests, where the ratio between variances are measured. ANOVA F-test method can be applied to detect the most important features to minimize high data dimensionality. It is a common feature selection strategy for numerical input values and categorical target variables.

3) Chi-Square Feature Selection (CSFS): CSFS is used to evaluate the discrepancy from the expected distribution when the feature incidence is independent from class value [29]. It tests two individual examples to avoid overfitting, reduce computational time, and boost the system's accuracy. However, it can work with data values measured on a nominal scale. The differences between various participant groups can be easily estimated without any assumptions about the distribution.

4) Mutual Information based Feature Selection (MIFS): MIFS represents statistical independence that determines the relationships between random variables [30]. In brief, it detects the quantity of information one random value contains about another one. When it is used as a feature selection scheme, it gives the model a chance to evaluate the relevance of feature subsets depending on the output vector. By quantifying the gain, the system can make effective feature selection decisions.

5) Recursive Feature Elimination (RFE): RFE [31], [32] is effective at picking more relevant parameters in large training datasets. While using RFE, programmers should pay full attention to the number of features selection and the right algorithm implementation. It operates by looking for a subset of features for all columns of the training dataset and getting rid of some irrelevant features. At first, the classifier gets trained, and parameters whose absolute values are the smallest get eliminated until only the required ones remain.

D. Outlier Detection

Outliers refer to those data points, whose have a significant difference from common observations, for the variability of measurement, sampling issues, and experimental errors [33]. These values deviate outcomes from expected values in further analysis. So, we simply address them as deviant examples, unusual data, and special samples respectively. In many cases, they do not provide good enough outcomes for the presence of outliers. So, those values are required to handle and get more improved results. Among various methods, the interquartile range (IQR) method is widely used to find different types of outliers. In IQR method, three values such as first (Q1), second (Q2), third (Q3) quartiles are considered. Then, all other values that remain outside between Q1 and Q3 are called outliers. Different instances of the dataset are arranged in ascending order and placed them into four equal sections. Since IQR expands from the first to third quartiles, then the outcomes of IQR is Q3 – Q1. Hence, all records that are under the lower limit (Q1 – 1.5 IQR) and over the upper limit (Q3 + 1.5 IQR) are called outliers. Therefore, all outliers can be detected in this way. After detecting them, they can be dropped or replaced by another suitable values. These instances affect the result of different machine learning algorithms in a particular dataset.

E. Applying Baseline Classifiers

Different types of widely used classification methods namely baseline classifiers are useful to explore various kinds of records and analyze their performance. After outlier detection and removal from primary and ANOVA F-test, CSFS, MIFS, and RFE datasets, several widely used classifiers including Gaussian Naive Bayes (GNB) [34], [35], Logistic Regression (LR) [14], [36], Random Forest (RF) [37], [38], Decision Tree (DT) [22], Extreme Gradient Boosting (XGB) [39], [11], Gradient Boosting (GB) [23], K-Nearest Neighbour (KNN) [40], AdaBoost [41], Support Vector Machine (SVM) [21], Multi-layer Perceptron (MLP) [42], and Extra Trees (ET) [43] are used to investigate PD detection dataset more precisely.

F. Evaluation Metrics

Some performance metrics such as accuracy, AUC, F-measure, Geometric mean, Sensitivity, Specificity, false positive rate, false negative rate have been used to evaluate the results of individual classifier. These metrics are expressed as a function of True Positive (TP), True Negative (TN), False Negative (FN), False Positive (FP) values.

- **Accuracy** is one of the most common evaluation metrics for classification models. It refers to how accurate a classification method is. We can express it as,

$$Accuracy = \frac{TP + TN}{TP + FN + TP + TN} \tag{1}$$

- **AUC** characterizes how well positive classes are isolated from negative classes. It can be represented with TP rate (TPR) and TN rate (TNR) by following equations:

$$\text{AUC} = \frac{TPR + TNR}{2} \tag{2}$$

- F-Measure is a harmonic mean of precision and recall.

$$F - Measure = \frac{TP}{TP + 0.5(FP + FN)} \tag{3}$$

- **Geometric mean (G-mean)** is a measure of central tendency computed as the square root of specificity and sensitivity. The equation is

$$G - mean = \sqrt{\frac{TP}{TP + FN} \times \frac{TN}{TN + FP}} \tag{4}$$

- **Sensitivity** refers to the proportion of the positive events against positive predicted events. So,

$$Sensitivity = \frac{TP}{TP + FN} \tag{5}$$

- **Specificity** refers to the proportion of the negative events against predicted negative events. So,

$$Specificity = \frac{TN}{FN + FP} \tag{6}$$

- **False positive rate (Fall Out)** shows the ratio between the number of negative samples which falsely classifies as positive.

$$False\ positive\ rate = \frac{FP}{FP + TN} \tag{7}$$

- **False negative rate (Miss Rate)** shows the ratio between the number of positive samples, which falsely classified as negative.

$$False - negative\ rate = \frac{FN}{FN + TP} \tag{8}$$

IV. Experiment Result and Discussion

In this experiment, we implement different machine learning techniques such as feature selection, outlier detection and classification methods using scikit-learn library in python. From different feature subsets, we generate CFS, AVONA F-test, CSFS, MIFS, and RFS dataset as well as implemented IQR method to detect outliers. However, DT, KNN, GNB, SVM, LR, MLP, XGB, RF, ET, Adaboost, GB, and SGB has been used to investigate these subdatasets along with primary dataset. This experiment has been conducted on Google Colaboratory.

A. Performance Analysis of Classifiers for Primary Dataset

In this work, the outcomes of each classifier for primary dataset are represented at Table I. Among all classifiers, GNB provides the best findings with 82.50% accuracy, 82.50% AUC, 82.49% F-measure, 82.50% G-mean, 82.50% Sensitivity, 82.50% Specificity, and the lowest 17.50% fall out, and 17.50% miss rate. Then, LR shows the second highest results to investigate and detect PD patients. Another classifiers such as DT, KNN, SVM, MLP, XGB, RF, ET, Adaboost, and GB show good result in this work. However, MLP and SGD do not produce more improved outcomes to identify PD patients.

When we investigate various ROC curves of different classifiers, GNB provides more TPR than any other classifier (see Fig. 2). Besides, another classifiers display good TPR except MLP and SGD.

TABLE I. EXPERIMENTAL RESULTS OF DIFFERENT CLASSIFIERS FOR PRIMARY DATASET

Classifier	Accuracy	AUC	F-Measure	G-Mean	Sensitivity	Specificity	Fall Out	Miss Rate
DT	70.42	70.42	70.33	70.42	70.42	70.42	29.58	29.58
KNN	72.08	72.08	72.08	72.08	72.08	72.08	27.92	27.92
GNB	**82.50**	**82.50**	**82.50**	**82.50**	**82.50**	**82.50**	**17.50**	**17.50**
SVM	72.92	72.92	72.86	72.92	72.92	72.92	27.08	27.08
LR	77.08	77.08	77.08	77.08	77.08	77.08	22.92	22.92
MLP	57.08	57.08	54.70	57.08	57.08	57.08	42.92	42.92
XGB	74.58	74.58	74.55	74.58	74.58	74.58	25.42	25.42
RF	75.83	75.83	75.73	75.83	75.83	75.83	24.17	24.17
ET	77.08	77.08	76.91	77.08	77.08	77.08	22.92	22.92
AdaBoost	70.00	70.00	70.00	70.00	70.00	70.00	30.00	30.00
GB	70.83	70.83	70.76	70.83	70.83	70.83	29.17	29.17
SGD	51.67	51.67	51.33	51.67	51.67	51.67	48.33	48.33

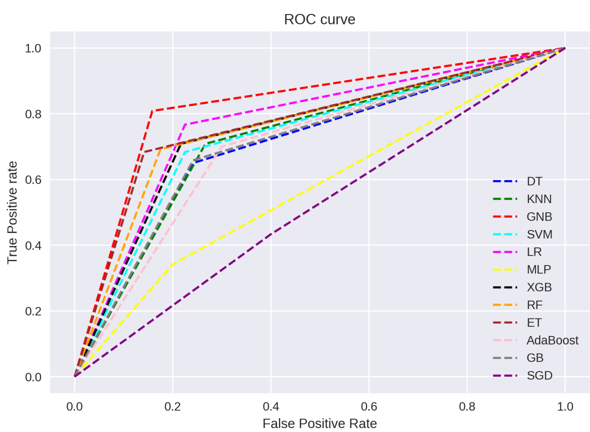

Fig. 2. ROC Curves of Individual Classifiers for Primary Dataset.

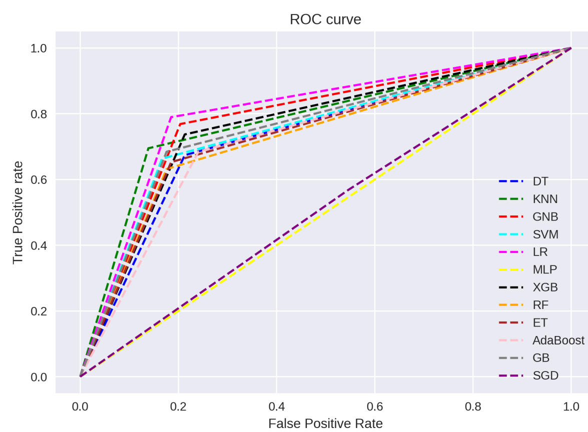

Fig. 3. ROC Curves of Individual Classifiers for CFS Dataset.

B. Performance Analysis of Classifiers for CFS Dataset

According to the outcomes at Table II, LR obtains the best 80.30% accuracy, 80.21% AUC, 80.30% f-measure, 80.21% g-mean, 80.30% sensitivity, 80.13% specificity where it shows 19.87% fall out and 19,70% miss rate. However, it does not exceed the highest of GNB for primary dataset. The results of several classifiers such as DT, KNN, SVM, XGB, Adaboost, and GB are improved for CFS than primary dataset. Instead, GNB, MLP, RF, and ET are slightly decreased than primary dataset in this work.

After observing ROC curves of each classifier, LR also shows more TPR than other classifiers (see Fig. 3). However, MLP and SGD do not provide good TPR like most of the classifiers in this work.

C. Performance Analysis of Classifiers for ANOVA F-test Dataset

In the classification result of Table III, GNB obtained the best outcomes for ANOVA F-test dataset and does not give improved results compared to primary dataset (81.42% accuracy, 81.41% AUC, 81.42% F-measure, 81.41% G-mean, 81.42% Sensitivity, 81.40% Specificity, 18.60% fall out, 18.58% miss out). Also, the degradation of results are noticed for KNN, SVM, MLP, RF, ET, and SGD. However, we noticed a performance boost for DT, LR, XGB, AdaBoost, and GB respectively.

Then, when we consider ROC curves of different classifier at Fig. 4, GNB shows the highest TPR to detect PD more precisely. Besides, LR, DT, KNN, SVM, XGB, RF, ET, Adaboost, and GB also represent good outcomes in this work.

D. Performance Analysis of Classifiers for CSFS Dataset

Then, GNB gives the best performance (80% accuracy, 79.74% AUC, 79.87% F-measure, 79.74% G-mean, 80% Sensitivity, 79.48% Specificity, 20.52% fall out, 20% miss rate) whereas it does not exceed the outcomes for primary dataset (see Table IV). Also, many classifiers like KNN, SVM, MLP, XGB, RF, ET, AdaBoost, and GB are not generated good results where DT, LR, and SGD show improved results than primary dataset.

TABLE II. EXPERIMENTAL RESULTS OF DIFFERENT CLASSIFIERS FOR CFS DATASET

Classifier	Accuracy	AUC	F-Measure	G-Mean	Sensitivity	Specificity	Fall Out	Miss Rate
DT	73.40	73.04	73.29	73.04	73.40	72.67	27.33	26.60
KNN	78.33	77.79	78.12	77.79	78.33	77.26	22.74	21.67
GNB	78.33	78.24	78.33	78.24	78.33	78.15	21.85	21.67
SVM	75.37	74.82	75.14	74.82	75.37	74.28	25.72	24.63
LR	**80.30**	**80.21**	**80.30**	**80.21**	**80.30**	**80.13**	**19.87**	**19.70**
MLP	53.20	50.00	36.95	49.90	53.20	46.80	53.20	46.80
XGB	76.35	76.19	76.34	76.19	76.35	76.03	23.97	23.65
RF	73.40	72.78	73.09	72.78	73.40	72.17	27.83	26.60
ET	73.89	73.37	73.67	73.37	73.89	72.85	27.15	26.11
AdaBoost	72.41	72.17	72.37	72.17	72.41	71.93	28.07	27.59
GB	75.86	75.41	75.71	75.41	75.86	74.97	25.03	24.14
SGD	50.74	51.11	50.63	51.10	50.74	51.47	48.53	49.26

TABLE III. EXPERIMENTAL RESULTS OF DIFFERENT CLASSIFIERS FOR ANOVA F-TEST DATASET

Classifier	Accuracy	AUC	F-Measure	G-Mean	Sensitivity	Specificity	Fall Out	Miss Rate
DT	73.89	73.86	73.88	73.86	73.89	73.83	26.17	26.11
KNN	68.58	68.47	68.45	68.47	68.58	68.36	31.64	31.42
GNB	**81.42**	**81.41**	**81.42**	**81.41**	**81.42**	**81.40**	**18.60**	**18.58**
SVM	68.58	68.47	68.45	68.47	68.58	68.36	31.64	31.42
LR	79.65	79.64	79.65	79.64	79.65	79.63	20.37	20.35
MLP	50.88	50.00	34.32	49.99	50.88	49.12	50.88	49.12
XGB	76.55	76.52	76.54	76.52	76.55	76.49	23.51	23.45
RF	75.22	75.12	75.13	75.12	75.22	75.02	24.98	24.78
ET	71.68	71.61	71.63	71.61	71.68	71.54	28.46	28.32
AdaBoost	73.45	73.43	73.45	73.43	73.45	73.40	26.60	26.55
GB	72.12	72.14	72.13	72.14	72.12	72.15	27.85	27.88
SGD	50.00	49.48	45.16	49.47	50.00	48.95	51.05	50.00

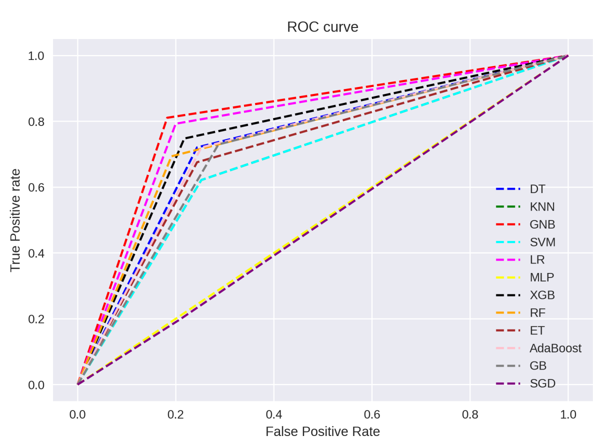

Fig. 4. ROC Curves of Individual Classifiers for ANOVA F-test Dataset.

When the ROC curves of different classifiers are observed (see Fig. 5), the curves of GNB and LR are very close to each other, but GNB is the best classifier to represent this curve. Again, MLP and SGD show its low TPR for CSFS dataset analysis.

E. Performance Analysis of Classifiers for MIFS Dataset

In this case, the outcomes of GNB and LR are very close to each other (see Table V). But, GNB shows slightly improved result than LR (79.29% accuracy, 79.28% AUC, 79.29% F-measure, 0.7928 G-mean, 79.29% Sensitivity, 79.28% Specificity, 20.71% fall out, and 20.7% miss rate). But it is not exceed GNB result for primary dataset. However, some classifiers like KNN, SVM, MLP, RF, ET, and SGD provide worsen results in MIFS dataset. However, the results of DT, LR, XGB, Adaboost, and GB are given a few improved result for MIFS than primary dataset.

However, the ROC curve of GNB and LR are almost same for MIFS dataset (see Fig. 6). Another classifiers also display good ROC curve except MLP and SGD.

TABLE IV. EXPERIMENTAL RESULTS OF DIFFERENT CLASSIFIERS FOR CSFS DATASET

Classifier	Accuracy	AUC	F-Measure	G-Mean	Sensitivity	Specificity	Fall Out	Miss Rate
DT	70.45	70.33	70.41	70.33	70.45	70.21	29.79	29.55
KNN	70.91	70.74	70.83	70.74	70.91	70.57	29.43	29.09
GNB	**80.00**	**79.74**	**79.87**	**79.74**	**80.00**	**79.48**	**20.52**	**20.00**
SVM	67.73	67.50	67.59	67.50	67.73	67.28	32.72	32.27
LR	78.18	78.02	78.12	78.02	78.18	77.86	22.14	21.82
MLP	51.36	49.56	35.17	49.53	51.36	47.76	52.24	48.64
XGB	71.36	71.14	71.24	71.14	71.36	70.92	29.08	28.64
RF	72.73	72.46	72.55	72.46	72.73	72.19	27.81	27.27
ET	71.82	71.52	71.59	71.52	71.82	71.21	28.79	28.18
AdaBoost	68.18	68.24	68.19	68.24	68.18	68.30	31.70	31.82
GB	67.27	67.16	67.24	67.16	67.27	67.05	32.95	32.73
SGD	55.00	53.70	48.25	53.68	55.00	52.40	47.60	45.00

TABLE V. EXPERIMENTAL RESULTS OF DIFFERENT CLASSIFIERS FOR MIFS DATASET

Classifier	Accuracy	AUC	F-Measure	G-Mean	Sensitivity	Specificity	Fall Out	Miss Rate
DT	74.01	73.99	73.94	73.99	74.01	73.97	26.03	25.99
KNN	70.04	70.03	70.00	70.03	70.04	70.01	29.99	29.96
GNB	**79.30**	**79.29**	**79.29**	**79.29**	**79.30**	**79.28**	**20.72**	**20.70**
SVM	69.16	69.16	69.16	69.16	69.16	69.15	30.85	30.84
LR	**79.30**	**79.29**	79.28	**79.29**	**79.30**	79.27	20.73	**20.70**
MLP	50.22	50.00	33.58	50.00	50.22	49.78	50.22	49.78
XGB	74.89	74.87	74.85	74.87	74.89	74.85	25.15	25.11
RF	72.25	72.22	72.15	72.22	72.25	72.20	27.80	27.75
ET	75.33	75.31	75.30	75.31	75.33	75.30	24.70	24.67
AdaBoost	72.69	72.67	72.65	72.67	72.69	72.66	27.34	27.31
GB	72.25	72.24	72.25	72.24	72.25	72.24	27.76	27.75
SGD	50.22	50.26	49.73	50.26	50.22	50.31	49.69	49.78

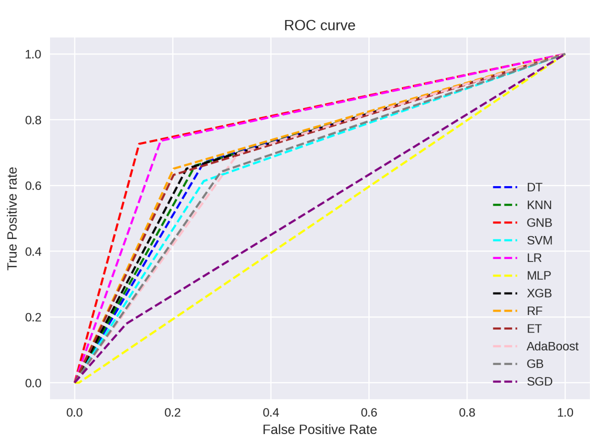

Fig. 5. ROC Curves of Individual Classifiers for CSFS Dataset.

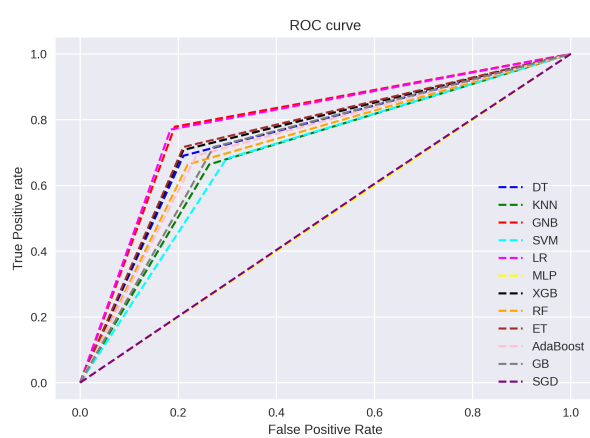

Fig. 6. ROC Curves of Individual Classifiers for MIFS Dataset.

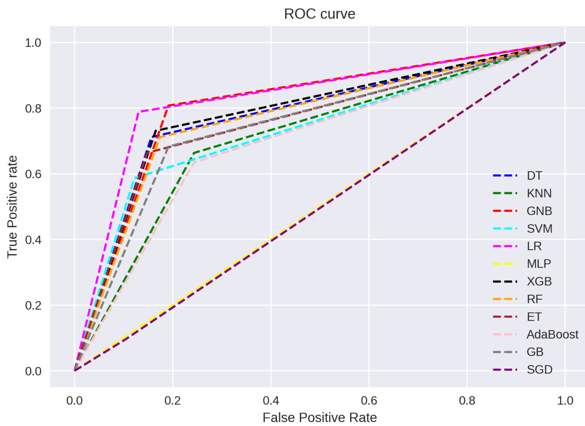

Fig. 7. ROC Curves of Individual Classifiers for RFE Dataset.

F. Performance Analysis of Classifiers for RFE Dataset

In this case, Table VI shows individual performance for RFE dataset where LR shows the highest result with 83.11% accuracy, 82.90% AUC, 83.06% F-measure, 82.90% G-mean, 83.11% Sensitivity, 82.70% Specificity, 17.30% fall out, and 16.89% miss rate. Therefore, it outperforms the best performance of GNB for primary dataset. A few improved results are found for some classifier excluding KNN, GNB, MLP, ET, AdaBoost, and SGB for RFE dataset.

Also, LR shows the best ROC curve whose represent more TPR than any other classifier for RFE dataset (see Fig. 7).

As we observe the performance measures and ROC curves of different classifier, LR determine the best outcomes for RFE dataset. But, these results are not found more stable in various cases. After observing the results of primary and its generated subdatasets, different classifiers give better outcomes and feature reduction methods are shown effective findings to detect PD patients. Also, we scrutinize the average results of different classifier which represents at Table VII. In this case, GNB displays the best average outcomes among all classifiers. Likewise, LR provides the second highest average outcomes in this analysis. Then, RF, XGB, ET, DT, KNN, GB, and AdaBoost give well average results like previous observations in the primary and its sub datasets. MLP and SGD do not represent good average outcomes in this work.

This proposed framework is integrated more feature selection and classification method than other existing works [14], [17], [20], [8], [44]. To evaluate its results, we consider various kinds of evaluation metrics where different previous works [21], [2], [23] has not maintained such types of evaluation. Along with best feature selection and classification methods, this framework also explores the most stable classifier which can provide better outcome in any types of transformation and experimental settings.

V. Conclusion and Future Work

This research has identified a reliable technique for feature selection of PD dataset with more simplicity, less running time, and cost-effectiveness. First, we explore insignificant features using different methods, remove them and generate sub datasets. However, the IQR method has been applied to detect outliers and prune them. Then, a lot of classifiers are used to investigate different types of PD datasets and compared them with primary dataset. In this case, LR shows the highest outcomes for RFE-based method. Besides, GNB is the most stable method to investigate Parkinson acoustic instances. This method can be potentially applied to similar types of datasets to obtain better solutions, distinguish between normal and sick people, and lessen diagnosis costs. Some feature selection and classification methods are provided random outcomes due to some infrastructural settings. In future, we would like to work on different limitations and gathered more widely used technologies to provide more satisfactory outcomes for detecting PD.

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TABLE VI. EXPERIMENTAL RESULTS OF DIFFERENT CLASSIFIERS FOR RFE DATASET

Classifier	Accuracy	AUC	F-Measure	G-Mean	Sensitivity	Specificity	Fall Out	Miss Rate
DT	78.08	77.75	77.95	77.75	78.08	77.42	22.58	21.92
KNN	71.23	71.00	71.16	71.00	71.23	70.77	29.23	28.77
GNB	80.82	80.82	80.83	80.82	80.82	80.82	19.18	19.18
SVM	73.97	73.24	73.32	73.24	73.97	72.51	27.49	26.03
LR	**83.11**	**82.90**	**83.06**	**82.90**	**83.11**	**82.70**	**17.30**	**16.89**
MLP	52.51	50.00	36.16	49.94	52.51	47.49	52.51	47.49
XGB	78.54	78.28	78.46	78.28	78.54	78.02	21.98	21.46
RF	77.17	76.88	77.07	76.88	77.17	76.59	23.41	22.83
ET	76.26	75.78	75.99	75.78	76.26	75.31	24.69	23.74
AdaBoost	69.86	69.56	69.73	69.56	69.86	69.25	30.75	30.14
GB	74.89	74.57	74.76	74.57	74.89	74.25	25.75	25.11
SGD	51.60	49.59	42.21	49.55	51.60	47.58	52.42	48.40

TABLE VII. AVERAGE CLASSIFICATION RESULTS OF INDIVIDUAL CLASSIFIERS

Classifier	Accuracy	AUC	F-Measure	G-Mean	Sensitivity	Specificity	Fall Out	Miss Rate
DT	73.38	73.23	73.30	73.23	73.38	73.09	26.91	26.62
KNN	71.86	71.69	71.77	71.69	71.86	71.51	28.49	28.14
GNB	**80.39**	**80.33**	**80.37**	**80.33**	**80.39**	**80.27**	**19.73**	**19.61**
SVM	71.29	71.02	71.09	71.02	71.29	70.75	29.25	28.71
LR	79.60	79.52	79.58	79.52	79.60	79.45	20.55	20.40
MLP	52.54	51.11	38.48	51.07	52.54	49.67	50.33	47.46
XGB	75.38	75.26	75.33	75.26	75.38	75.15	24.85	24.62
RF	74.43	74.22	74.29	74.22	74.43	74.00	26.00	25.57
ET	74.34	74.11	74.18	74.11	74.34	73.88	26.12	25.66
AdaBoost	71.10	71.01	71.06	71.01	71.10	70.92	29.08	28.90
GB	72.20	72.06	72.14	72.06	72.20	71.92	28.08	27.80
SGD	51.54	50.97	47.88	50.96	51.54	50.40	49.60	48.46

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Vietnamese Sentence Paraphrase Identification using Pre-trained Model and Linguistic Knowledge

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***Abstract*—The paraphrase identification task identifies whether two text segments share the same meaning, thereby playing a crucial role in various applications, such as computer-assisted translation, question answering, machine translation, etc. Although the literature on paraphrase identification in English and other popular languages is vast and growing, the research on this topic in Vietnamese remains relatively untapped. In this paper, we propose a novel method to classify Vietnamese sentence paraphrases, which deploys both the pre-trained model to exploit the semantic context and linguistic knowledge to provide further information in the identification process. Two branches of neural networks built in the Siamese architecture are also responsible for learning the differences among the sentence representations. To evaluate the proposed method, we present experiments on two existing Vietnamese sentence paraphrase corpora. The results show that for the same corpora, our method using the PhoBERT as a feature vector yields 94.97% F1-score on the VnPara corpus and 93.49% F1-score on the VNPC corpus. They are better than the results of the Siamese LSTM method and the pre-trained models.**

Keywords*—*Paraphrase identification; Vietnamese; pre-trained model; linguistics; neural networks

I. INTRODUCTION

Paraphrase identification, a task that whether two text segments with different wordings express similar meaning, is critical in various Natural Language Processing (NLP) applications, such as text summarization, text clustering, computer-assisted translation, and, especially plagiarism detection [1]. Paraphrases can take place at different linguistic levels, ranging from word and phrase to sentence and discourse. For instance, Neculoiu et al. [2] deployed Siamese recurrent networks to determine similarity among texts, normalizing job titles that are paraphrases at the word level. Meanwhile, to detect paraphrases at the discourse level, Liu et al. [3] calculated semantic equivalence among academic articles published in 2017 to identify documents with similar themes and contents.

Paraphrase corpora are corpora that contain pairs of sentences that convey the same meaning. Regarding Vietnamese, there have been two paraphrase corpora published for the language, one of which is vnPara by Bach et al. [4], while the other is VNPC (Vietnamese News Paraphrase Corpus) by Nguyen-Son et al. [5]. Both of these corpora consist of sentence-level paraphrases. Examples of paraphrases and non-paraphrases extracted from vnPara and VNPC are shown in Tables I and II, respectively.

While string matching is the simplest solution to the paraphrase identification question in theory, it does not yield high accuracy rates in practice. Two segments of text that are constructed with different strings can still be paraphrases. On the contrary, various text segments that have overlapping substrings can denote different interpretations, and thus they are non-paraphrases.

TABLE I. EXAMPLES OF VIETNAMESE PARAPHRASES AND THEIR TRANSLATION INTO ENGLISH

Paraphrase		**Corpus**
ASA sẽ tìm thấy người ngoài hành tinh trong 20 năm tới.	ASA nói có thể sẽ tìm thấy người ngoài hành tinh trong 20 năm tới.	vnPara
ASA will find aliens in the next 20 years	ASA says that it's possible to find aliens in the next 20 years	
Đáng chú ý, mã độc này chưa hoạt động mà ở chế độ "ngủ đông", chờ lệnh tấn công.	Đáng chú ý mã độc này chưa hoạt động mà ở chế độ nằm vùng.	VNPC
Remarkable, this malware has not been working yet but is in "hibernate" mode, wait for an attack.	Remarkable, this malware has not been working yet but is in "stand-by" mode.	

TABLE II. EXAMPLES OF VIETNAMESE NON-PARAPHRASES AND THEIR TRANSLATION INTO ENGLISH

Non-paraphrase		**Corpus**
Các gián điệp Trung Quốc đã tấn công hệ thống mạng của một nước thuộc khu vực Đông Nam Á.	Các gián điệp Trung Quốc đã tấn công hệ thống mạng của một tổ chức nghiên cứu lớn của chính phủ Canada, giới chức Canada ngày 29/7 cho biết.	vnPara
Chinese spies have attacked the network system of a country in Southeast Asia.	Chinese spies have attacked a big Canada research organization's network system, from Canada authorities - 29/7.	
Cầu thủ trẻ đắt giá thứ ba mà Real từng đào tạo là Alvaro Negredo.	Một số cầu thủ khác từng trưởng thành từ lò đào tạo trẻ của Real là Cheryshev, Joselu, Diego Lopez và Rodrigo Moreno	VNPC
The third most valuable young player who Real has trained is Alvaro Negredo.	Some other players who have grown up at Real's youth academy are Cheryshev, Joselu, Diego Lopez and Rodrigo Moreno.	

According to Suzuki et al. [1], these two types of paraphrases and non-paraphrases are categorized as a non-trivial class, whose instances hold a key role in the paraphrase identification task. Table III presents examples of non-trivial instances extracted from VNPC. The WOR column in this stable represents the word overlap rate of two given sentences, which is calculated using Jaccard index [7], where X and Y denote the set of words of those two sentences:

TABLE III. EXAMPLES OF NON-TRIVIAL INSTANCES EXTRACTED FROM VNPC

Sentences pair		Type	WOR
Nadal đánh bóng ra ngoài, mất mini-break sớm.	Game đầu thứ chín, Nadal có tới bốn cú đánh bóng ra ngoài, để mất break.	paraphrase	21.05%
Nadal hit the ball out and lost the mini-break early.	In the ninth game of the match, Nadal hit four balls out and lost the break.		
Link sopcast xem trực tiếp U23 Đức vs U23 Nigeria trong khuôn khổ bán kết bóng đá nam Olympic 2016 được cập nhật liên tục tại đây.	Link sopcast xem trực tiếp U23 Brazil vs U23 Honduras trong khuôn khổ bán kết bóng đá nam Olympic 2016.	non-paraphrase	77.27%
Sopcast link to watch U23 Germany vs U23 Nigeria in the semi-final of the Men's Olympic Football 2016 is updated continuously here.	Sopcast link to watch U23 Brazil vs U23 Honduras in the semi-final of the Men's Olympic Football 2016.		

$$WOR(X,Y) = \frac{|X \cap Y|}{|X \cup Y|} = \frac{|X \cap Y|}{|X| + |Y| - |X \cap Y|} \quad (1)$$

The accurate identification of non-trivial paraphrases and non-paraphrases requires methods that can exploit the semantic differences of texts. Hitherto, the paraphrase identification task has been a focus in various studies in English and some other popular languages. In particular, works by Yin et al. [8], Mueller et al. [9], Jiang et al. [10], Zhou et al. [11], among many others, have proposed various methods, ranging from simple string-matching to machine learning and deep learning techniques. In contrast, research on this topic in Vietnamese remains relatively limited, with only two studies conducted by Bach et al. [4] and Nguyen-Son et al. [5].

On the one hand, previous literature on the paraphrase identification task in Vietnamese also depends heavily on the string-based methods. For instance, Bach et al. [4] use nine string-based similarity measures combined with seven-string pairs to represent a sentence. As discussed earlier, this method has proven to be rather ineffective in classifying non-trivial instances. On the other hand, while the deep learning techniques can be applied to Vietnamese, they require an extensive paraphrase corpus, the construction of which demands high costs of human and machinery resources. This creates apparent obstacles for conducting research on paraphrase identification in the language.

To address these problems, in this study, we propose a novel method to identify sentence paraphrases in Vietnamese implementing a combination of pre-trained models such as the Bidirectional Encoder Representations from Transformers (BERT) model [12], XML-R [13] and PhoBERT [14] and linguistic knowledge. The pre-trained models are used as a feature extractor to embed semantic context information in the representation vectors of Vietnamese sentences and help to overcome the lack of paraphrase corpora. Besides, linguistic knowledge also aids in providing additional information for the training process of Siamese architecture. The rest of the paper is organized as follows. We present previous studies that are relevant to the current study in Section 2, and then propose a novel method to identify sentence paraphrases in Vietnamese in Section 3. Section 4 contains our experiments on evaluating the performance of this method. Section 5 concludes the work and discusses future directions.

II. RELATED WORK

Various paraphrase identification and similarity measurement methods have been proposed for a range of languages. The methods can be categorized into four different groups of approaches: string-based, corpus-based, knowledge-based, and hybrid [15]. In this section, we first present the methods laid out in these four approaches and then discuss previous work conducted for the Vietnamese language.

A. String-based Approach

The advantage of this approach lies in its simplicity, as most of the methods are easy to implement. The main information is derived from the text itself, with little to no reliance on additional resources. However, this also lowers the accuracy of the approach, as all of these methods do not detect semantic similarity effectively, thereby failing to account for non-trivial cases, as discussed earlier.

First, among the similarity measures that are widely used across different applications is the Damerau-Levenshtein distance [16]. This measure considers the minimum number of operations needed to convert one text into the other. An operation can be either an insertion, a deletion, a substitution of a single character or a transposition of two consecutive characters.

Secondly, the n-gram comparison of two texts is also considered a common algorithm. An n-gram is a sequence of n elements of a text sample. These n elements can be characters, phonemes, syllables, or words, depending on the tasks and applications. Alberto et al. define the formula to calculate the text similarity value using n-grams as follows [17]:

$$\text{Similarity} = \frac{\text{Number of the same n-grams}}{\text{Total number of n-grams}} \quad (2)$$

Another popular similarity measure in not only this vein of research but also in other fields is the Jaccard similarity index. This measure is calculated by taking the ratio of the number of common words and the total number of distinct words of both texts [7]. Moreover, other methods, such as Euclid, Manhattan, and Cosine, typically represent texts in the form of vectors and then compute text similarity using the distance between these vectors, as shown below:

$$\text{Euclid distance} = \sqrt{\sum_{i=1}^{n}(X_i + Y_i)^2} \quad (3)$$

$$\text{Manhattan distance} = \sum_{i=1}^{n}|X_i - Y_i| \quad (4)$$

$$\text{Cosine similarity} = \frac{\sum_{i=1}^{n} X_i Y_i}{\sqrt{\sum_{i=1}^{n} X_i^2}\sqrt{\sum_{i=1}^{n} Y_i^2}} \quad (5)$$

In all of these formulas, X and Y denote the two representation vectors of two corresponding segments of text.

Furthermore, while these three measures are considered methods within the string-based approach, they are still utilized as objective functions in other methods in other approaches, especially in machine learning models. Given its straightforwardness implementation, the string-based approach can be found in applications that do not strictly rely on paraphrase identification. Since the processing occurs mainly on the input strings, these methods can be extended to the analyses of texts in a broad range of languages, including Vietnamese.

B. Corpus-based Approach

The methods of this approach exploit information from existing corpora to predict the similarity of input texts. The most common method in this approach is the Latent Semantic Analysis (LSA) [18], which assumes that words with similar meanings are co-occurrence in similar text segments. In this method, a matrix that represents the cohesion between words and text segments is first constructed from one or more given corpora. Then, its dimensions are reduced using the Singular Value Decomposition (SVD) technique. Finally, the similarity is calculated by the cosine similarity between the vectors which are the rows of the matrix.

Some methods use online corpora obtained from websites or search engine results. The advantage of these methods is that the extracted information is not only tremendously large, but it is also regularly updated. For instance, the Explicit Semantic Analysis (ESA) method uses Wikipedia articles as a data source to build representation vectors for texts [19]. Likewise, Cilibrasi et al. calculate the text similarity based on the statistics of results from the Google search engine for a given set of keywords [20].

In recent years, the deep learning technique on machine learning models has become more and more popular because of their efficiency in solving classification problems in various fields. In the paraphrase identification task, deep learning on the Siamese architecture for neural networks is the most popular method. The Siamese networks are dual-branch networks that share the same weights and are merged by an energy function. The Siamese architecture can learn the information about the differences between two input samples. Recently, the Siamese LSTM model is a well-known combination. Each input text is fed into an LSTM's sequence. The outputs of the LSTM's sequence are then merged by the Manhattan distance function in [9]. Meanwhile, Neculoiu et al. [2] use another feed-forward neural network which finetunes the output of LSTM layers before they are being merged by the cosine similarity function. Neculoiu et al. also use bi-directional LSTM's sequence to exploit the bi-directional context instead of the single LSTM's sequence as in [9].

The Google AI Research team then proposes the Bidirectional Encoder Representations from Transformers (BERT, 2018) model using Transformers as the model's core [12]. These Transformers are fully connected, which allows it to outperform the state-of-the-art models at that time for some NLP downstream tasks. The model has achieved high results in over six tasks of NLP, including text similarity and paraphrase identification. We implement this BERT model in the proposed method of our study.

The introduction of the BERT model also leads to the emergence of the Siamese BERT model. Reimers et al.'s (2019) Sentence BERT (SBERT) model [21] uses the Siamese architecture to help fine-tune BERT with some corpora, targeting specific tasks to improve sentence representation for each task. The results of this work in downstream tasks are better than those of the representation vectors obtained from BERT.

Based on Transformer-XL, Yang et al.'s (2019) XLNet model [22] is argued to yield better results than BERT. The research team pointed out some shortcomings of the BERT model such as inconsistencies between training and the fine-tuning task and parallel independent word predictions. To overcome these drawbacks, they utilize both Permutation Language Modeling (PLM) and Transformer-XL [23].

Besides the pretrained model BERT, Alexis Conneau et al. (2020) introduce the XML-R model (XML-RoBERTa) [13], which is a generic cross lingual sentence encoder that obtains state-of-the-art results on many cross-lingual understanding (XLU) benchmarks. It is trained on 2.5T of filtered CommonCrawl data in 100 languages, and Vietnamese is one of the supported languages.

Based on RoBERTa, Dat Quoc Nguyen and Anh Tuan Nguyen (2020) introduce the PhoBERT model [14]. PhoBERT outperforms previous monolingual and multilingual approaches, obtaining new state-of-the-art performances on four downstream Vietnamese NLP tasks of Part-of-speech tagging, Dependency parsing, Named-entity recognition and Natural language inference.

While this is a potential approach for Vietnamese, the lack of high-quality and large corpora remains an obstacle to adopt these methods to the language.

C. Knowledge-based Approach

Methods in this approach exploit the linguistic knowledge from knowledge bases such as semantic networks, ontology, etc. WordNet [24], the most popular semantic network, is often used to extract linguistic knowledge at the lexical level to recognize the similarity between texts. Meanwhile, BabelNet [25] is a new semantic network that covers 284 languages. The main disadvantage that comes with Babelnet is that it only provides API in Java in its free edition.

There are six semantic measures, three of which are based on information content, while the remaining three are based on the connection length in the network. The former measures are proposed in Resnik (res) [26], Lin (lin) [27], and Jiang & Conrath (in) [28], while the latter ones can be found in Leacock & Chodorow (lch) [29], Wu & Palmer (wup) [30], and Path Length (path). These measures are slightly different but can be interchangeable. Path Length is the most commonly used measure.

With the work of Le et al. [31] and BabelNet, we can apply this approach to Vietnamese. However, the Vietnamese semantic networks are not complete and still being updated, implying inconsistent results that would be yielded from the implementation of this approach alone.

D. Hybrid Approach

Mihalcea et al. (2006) combine two methods of the corpus-based approach with six measures of the knowledge-based approach to computing text similarity [32]. The results of the combination are better than those of each of the methods. Meanwhile, Li et al. (2006) calculate text similarity using the semantic vectors built from WordNet and Brown corpus [33]. Besides, the representation vector for word order also involves in the process of calculating the similarity of two sentences.

E. Vietnamese Sentence Paraphrase Identification

The work of Bach et al. in 2015 is among the first attempts to solve the paraphrase identification task for Vietnamese [4]. The important contribution of this work is the Vietnamese paraphrase corpus, vnPara, which is the first Vietnamese paraphrase corpus. The corpus is used to evaluate their proposed method, which is to construct a text representation vector from the combination of multiple similarity measures in the string-based approach for syntactic units such as words, syllables, part-of-speech (POS), nouns, verbs, etc. After this combination of measures and syntactic units with four machine learning methods, Bach et al. has achieved the highest results with the Support vector machine (SVM) when combining nine measures with seven syntax units.

Then, Nguyen-Son et al. (2018) propose a method that matches duplicate phrases and similar words [5]. First, this method matches all identical substrings of two sentences, and then eliminates stop words. Afterwards, WordNet is utilized to calculate the similarity for the remaining words. The experimental results of this method reveal that the vnPara corpus contains multiple paraphrase pairs that have a high rate of word overlap. Therefore, Nguyen-Son et al. introduce the construction of a new corpus, VNPC, which is argued to be more diverse than vnPara. In summary, most research on paraphrase identification for Vietnamese still rely heavily on the string-based approach, which is not ineffective in detecting semantic paraphrase identification.

III. Proposed Method

Since deep learning methods often require large corpora, the lack of Vietnamese paraphrase corpora creates challenges to researchers who plan to apply this technique to the language. Recently, the emergence of pre-trained models helps researchers overcome this obstacle. The pre-trained models such as BERT, XML-R and PhoBERT are most popular pre-trained models, especially for Vietnamese. Therefore, we take this advantage to construct our method.

Even though in theory, pre-trained models can effectively solve the paraphrase identification task for Vietnamese, we expect that this task can be improved with the addition of linguistic knowledge during the process. Devlin et al. [12] state that there are three ways to improve BERT, which are pre-training from scratch, fine-tuning the pre-trained model, and utilizing BERT as a feature extractor. However, linguistic knowledge cannot be used in the fine-tuning process, and training BERT and other pre-trained models from scratch is extremely costly. Therefore, feature extraction is the most plausible way to implement BERT in our method.

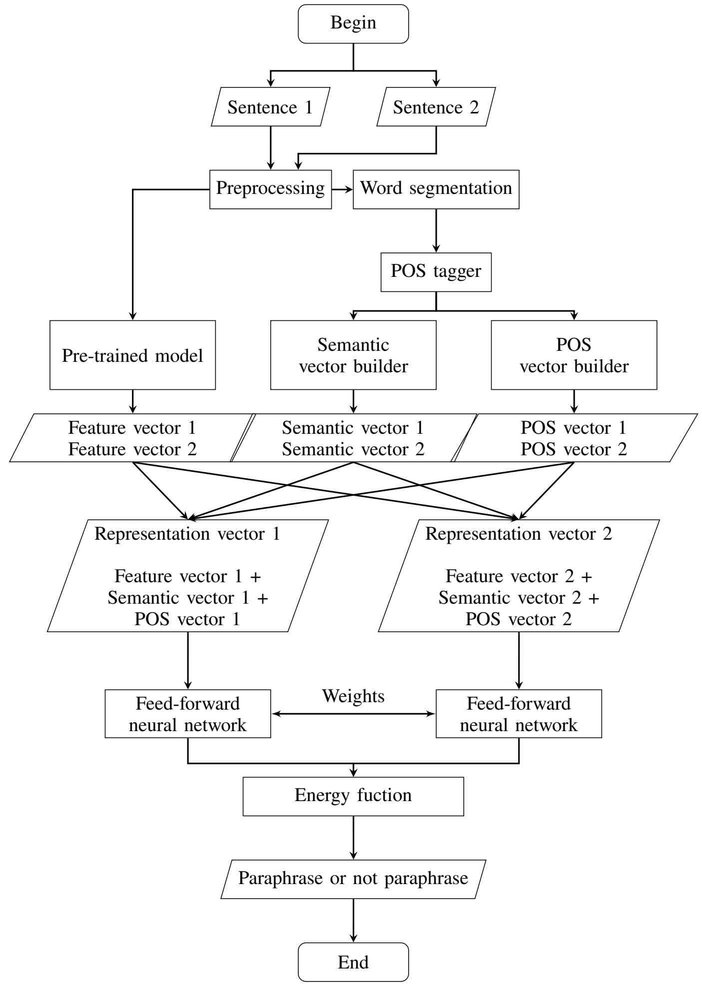

Fig. 1. Overview of the Proposed Method to Identify Vietnamese Sentence Paraphrase.

The proposed method follows a hybrid approach. In particular, it is a combination of the corpus-based approach and the knowledge-based approach to fully exploit the information gained from these two approaches.

We built three vectors for each input sentence:

- Feature vector achieved from pre-trained model.

- Semantic vector constructed by using WordNet.

- POS vector represents the POS of words in a sentence.

These three vectors then were joined together to form a sentence representation vector. There were two such vectors for two input sentences. These vectors were fed into a Siamese feed-forward neural network to train or predict. The overview of the proposed method is depicted in Fig. 1.

A. Preprocessing

The input pairs of sentences before being put into the main processing chain were normalized by regular expressions and Heuristic rules.

B. Features Extraction Using Pre-trained Model

Heretofore, simple word embedding models such as Word2Vec [34], GloVe [35], FastText [36], etc. are common methods used by many research groups to represent text in vector form. However, these models represent every word with a unique vector in all contexts. In contrast, the feature vector constructed from pre-trained model contains full information of the bi-directional context, thanks to Transformer blocks' multi-head self-attention mechanisms and fully connected architecture.

The features extracted from pre-trained model were the output of the Transformer blocks. For instance, BERT-Base with 12 Transformer blocks provided 12 real vectors for each token and BERT-Large with 24 Transformer blocks provided 24 vectors. The dimension of each vector was the number of hidden units of each layer. There were 768 dimensions for BERT-Base and 1,024 dimensions for BERT-Large.

C. Semantic Vector Construction

We followed the method of [33] to construct semantic vectors for a sentence pair. A semantic vector contained information on the semantic relatedness of the words in these sentences. These vectors were constructed by using a semantic network and statistical information of a corpus. In our work, we use Vietnamese WordNet which was constructed by Le et al. in 2016 [31] and the statistical information from [37].

From the list of words of the sentences pair, a set of unique words was constructed. The order of these words was preserved in the order of the words in the sentences.

Let M be a two-dimensional matrix containing the relatedness of each pair of words. The matrix M has n rows corresponding to n words of the considered sentence and m columns corresponding to m words in the set of unique words. The relatedness between w1 (line r) and w2 (column c) is calculated using the formula:

$$M(r,c) = \begin{cases} 1 & \text{if } w1=w2 \\ \text{PathLength}(w1,w2) & \text{if } w1 \neq w2 \\ 0 & \text{if } w1 \text{ or } w2 \text{ is not in Wordnet} \end{cases} \quad (6)$$

where WordNet.PathLength(w1, w2) is the Path Length similarity in WordNet of word w1 and word w2. Each element of the lexical vector s is the maximum value on a column of the matrix M:

$$s[c] = M(r,c) \text{ , } c = [1,m] \quad (7)$$

Finally, the semantic vector semVec is calculated using the formula:

$$semVec[c] = s[c] \times I(W1) \times I(W2) \quad (8)$$

where W1 and W2 are words that have the greatest relatedness s[c] on column c; I(W1) and I(W2) are the information content of the two corresponding words. The information content I(w) of word w is calculated by the frequency of w in a corpus:

TABLE IV. PROCESS OF CONSTRUCTING THE SEMANTIC VECTOR FOR THE FIRST SENTENCE

	anh	**ấy**	**là**	**giáo_viên**	**nhà_giáo**
anh (he)	1				
ấy (he)		1			
là (is)			1		
giáo_viên (teacher)				1	0.33
s	1	1	1	1	0.33
Weights	I(anh)	I(ấy)	I(là)	I(giáo_viên)	I(giáo_viên)
	I(anh)	I(ấy)	I(là)	I(giáo_viên)	I(nhà_giáo)
Semantic vector	0.1026	0.1474	0.0654	0.2597	0.1065

$$I(w) = -\frac{loglogp(w)}{loglog(N+1)} = 1 - \frac{loglog(n+1))}{loglog(N+1)} \quad (9)$$

where p(w) is the relative frequency of w in a corpus, N is the number of words in the corpus and n is the frequency of the word w in the corpus.

Table IV shows the process of constructing the semantic vector for the first sentence in this sentences pair:

- Sentence 1: anh ấy là giáo_viên (he is a teacher)

- Sentence 2: anh ấy là nhà_giáo (he is an educator)

The semantic vector must be padded with zero-value to have a fixed length. According to the statistics in [37] about the average length of sentence (in words), we assume that the longest sentence may have a length of 50 words. Thus, we construct the semantic vector with a fixed length of 100.

D. Parts-of-speech (POS) Vector Construction

WordNet only accepts four simple parts-of-speech which are noun, verb, adjective, and adverb so that the semantic vector does not contain full information of the sentence's parts-of-speech. Therefore, we also used the POS vector to provide more information to the model. To construct a POS vector, each word in a sentence was tagged with its part-of-speech to create a list of parts-of-speech for each sentence. These POS lists were then represented as real vectors by using the FastText model [36]. To train this model, we used the Vietnamese Treebank corpus [38] with 10,000 POS tagged sentences. An output vector of the FastText model had a fixed length of 100.

E. Siamese Feed-forward Neural Network (SFFNN)

For each input sentence, the feature vector obtained from pre-trained model, the semantic vector, and the POS vector were concatenated to form the representation vector (Fig. 3). Sentence paraphrase identification task has an input of two sentences. Therefore, we generated two representation vectors.

To make the neural network learn the similarity between two sentences, we applied the Siamese architecture to the feed-forward neural network. Fig. 2 depicts a Siamese feed-forward neural network. The feed-forward neural network was constructed by multiple dense (fully connected) layers. The number of layers and hidden units will be presented in

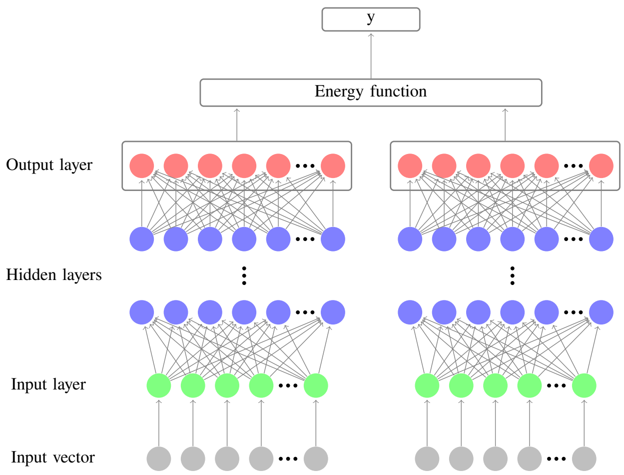

Fig. 2. Overview of the Proposed Method to Identify Vietnamese Sentence Paraphrase.

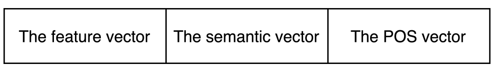

Fig. 3. Forming the Representation Vector.

subsection 4.2.2. The activation function of hidden layers. The input layer was the ReLU function, and the output layer was the sigmoid function. The ReLU function is often used as the activation function in hidden layers due to its simplicity. Besides, the constant gradient of ReLUs results in faster learning and allows ReLU to overcome the defect of sigmoid function when the absolute value of the input is great.

The neural network was trained using the backpropagation algorithm and the training only stopped when the value of the energy function no longer changed. We used the Mean Squared Error (MSE) function as an error function for the gradient descent method. There are three similarity functions commonly used as energy functions in the text similarity task. They are Euclid, Manhattan, and Cosine. The study of Chopra et al. [39] shows that the Euclid and Cosine functions using the normalized function l2 instead of l1 in the similarity function can lead to undesirable plateaus in the overall objective function. Therefore, we used the Manhattan similarity function as the energy function in our model.

IV. Experiment

A. Corpora

The experiments in this paper were conducted on two main corpora: vnPara [4] and VNPC [5].

1) vnPara: VnPara has become a common Vietnamese paraphrase corpus in various studies [5][6]. To construct vnPara corpus, Bach et al. [4] first collected articles from online newspaper websites such as dantri.com.vn, vnexpress.net, thanhnien.com.vn, and so on. As shown in Table V, sentences extracted from the articles were paired if they have multiple words in common. These sentence pairs were labeled manually by two people.

TABLE V. Examples from vnPara and their Translation into English

Sentences pair		**Is Paraphrase**
ASA sẽ tìm thấy người ngoài hành tinh trong 20 năm tới.	ASA nói có thể sẽ tìm thấy người ngoài hành tinh trong 20 năm tới.	1
ASA will find aliens in the next 20 years.	ASA says that it's possible to find aliens in the next 20 years	
Các gián điệp Trung Quốc đã tấn công hệ thống mạng của một nước thuộc khu vực Đông Nam Á.	Các gián điệp Trung Quốc đã tấn công hệ thống mạng của một tổ chức nghiên cứu lớn của chính phủ Canada, giới chức Canada ngày 29/7 cho biết.	0
Chinese spies have attacked the network system of a country in Southeast Asia.	Chinese spies have attacked the network of a prominent Canadian government research organization, the Canadian officials say on July 29.	
Bà đã cho ra đời 15 cuốn tiểu thuyết, nhiều tập truyện ngắn và các bài bình luận văn học.	Trong suốt sự nghiệp của mình, bà đã sáng tác 15 tiểu thuyết, nhiều truyện ngắn và nhận được gần 20 giải thưởng văn học lớn.	1
She has published 15 novels, many short stories, and literary studies.	In her entire career, she has written 15 novels, many short stories and achieve about 20 major literary awards.	

TABLE VI. Examples from VNPC and their Translation into English

Sentences pair		**Is Paraphrase**
Đáng chú ý, mã độc này chưa hoạt động mà ở chế độ "ngủ đông", chờ lệnh tấn công.	Đáng chú ý mã độc này chưa hoạt động mà ở chế độ nằm vùng.	1
Remarkable, this malware has not been working yet but is in "hibernate" mode, wait for an attack.	Remarkable, this malware has not been working yet but is in "stand-by" mode.	
Trần Thị Thu Ngân đăng quang ngôi vị cao nhất của cuộc thi Hoa hậu Bản sắc Việt toàn cầu 2016	Trần Thị Thu Ngân đăng quang Hoa hậu Bản sắc Việt toàn cầu 2016	1
Tran Thi Thu Ngan crowned the highest position in Miss Vietnam Global Heritage 2016	Tran Thi Thu Ngan crowned Miss Vietnam Global Heritage 2016	
Cầu thủ trẻ đắt giá thứ ba mà Real từng đào tạo là Alvaro Negredo.	Một số cầu thủ khác từng trưởng thành từ lò đào tạo trẻ của Real là Cheryshev, Joselu, Diego Lopez và Rodrigo Moreno	0
The third most valuable young player who Real has trained is Alvaro Negredo.	Some other players who have grown up at Real's youth academy are Cheryshev, Joselu, Diego Lopez and Rodrigo Moreno.	

2) VNPC: VNPC was constructed by Nguyen-Son et al. when they experimented with their proposed method in [5]. According to their experiment result, VNPC was argued to be more diverse than vnPara.

To build this corpus, first of all, the pairs of sentences were extracted from 65,000 pages of 15 Vietnamese news websites. Nguyen-Son et al. used their proposed method to measure the similarity of the obtained pairs. 3,134 candidates were selected using a predefined threshold. As shown in Table VI, these sentences formed paraphrase pairs, which were manually labeled.

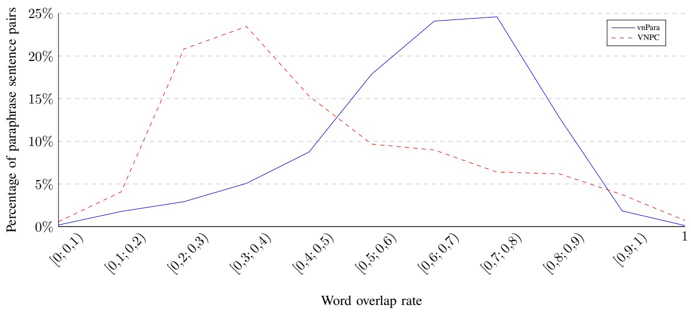

Fig. 4. Distribution of Paraphrase Cases of vnPara and VNPC according to the Word Overlap Ratio.

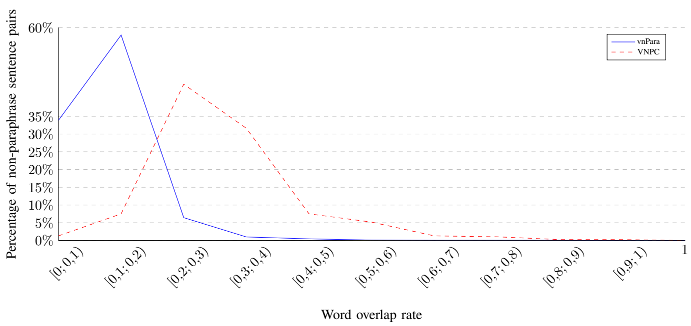

Fig. 5. Distribution of Non-paraphrase Cases of vnPara and VNPC according to the Word Overlap Ratio.

3) Some Properties of the Two Corpora:

a) Number of sentence pairs per class.: The number of sentence pairs of the vnPara corpus is 3,000 and the number of sentence pairs of the VNPC is 3,134. The VNPC corpus contains 2,748 paraphrase pairs and 386 non paraphrase pairs. Meanwhile, the vnPara corpus has the same number of paraphrase pairs and non paraphrase pairs is 1,500 sentence pairs.

b) Number of non-trivial sentence pairs.: Research by Yui Suzuki et al. [1] shows that the importance of non-trivial paraphrase or non- paraphrase sentence pairs. The authors define that a non-trivial paraphrase sentence pair is a paraphrase sentence pair with a small ratio of words overlap (WOR) between two sentences. On the contrary, a non-trivial non- paraphrase sentence pair is non-paraphrase sentence pair with a large ratio of words overlap between two sentences. We have made statistics on the rate of word overlap of sentence pairs in both corpora. The word overlap rate is calculated using the formula for calculating the Jaccard index.

Fig. 4 shows that the VNPC corpus contains more non-trivial paraphrase sentence pairs than vnPara. Fig. 5 shows that both corpora contain very few non-trivial non-paraphrase sentence pairs. The vnPara corpus almost does not contain any paraphrase sentence pair with a overlap rate from 0.5.

B. Experimental Setup

1) Evaluation Method: To compare the result of our method with the results of the vnPara and VNPC studies, we conducted the experiment in the same manner. Each corpus was divided into 5 folds randomly to perform a 5-fold cross validation test. We also used the same metrics which were accuracy and F1 score as follows:

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{10}$$

$$Precision = \frac{TP}{TP + FP} \tag{11}$$

$$Recall = \frac{TP}{TP + FN} \tag{12}$$

$$Recall = 2 \text{ x } \frac{\text{Precision x Recall}}{\text{Precision + Recall}} \tag{13}$$

where TP is true positive (a correct prediction of paraphrase), TN is true negative (a correct prediction of non-paraphrase), FP is false positive (a wrong prediction of paraphrase), and FN is false negative (a wrong prediction of non-paraphrase).

2) Configuration of Feed-forward Neural Network: The configuration of feed-forward neural network includes 12 hidden layers, 768 hidden units. We chose this configuration for experiments on the vnPara corpus and VNPC corpus.

C. Experimental Results

The experiments with our proposed method were performed with some different configurations of stop words, BERT's output layer, and BERT's output pooling strategies. We achieved the best result when testing our method with the configuration in which we kept stop words, used the second-to-last layer of pre-trained output, and utilized an average pooling strategy to get the feature vector. When experimenting with the Siamese LSTM model in the article [9], we used the pre-trained Vietnamese Word2Vec model of Vu et al. [40].

Tables VII and VIII show the results of experiments we conducted on vnPara and VNPC with several methods. The result of each method is presented by each row in the tables. Each method is evaluated by the accuracy and the F1 score. Each table shows the available results from previous studies for Vietnamese, the results of the Siamese LSTM model [9], the results of original pre-trained models, and the results of our method. The results of our method are presented in three rows according to three different configurations of additional vectors: adding semantic vector, adding the POS vector, and adding both semantic vector and POS vector.

We also compute the F1 score on each word overlap rate range with the proposed method as figures similar to the 4 and 5. The calculation of the F1 score is divided into two cases: paraphrase cases and non-paraphrase cases to assess the effect of non-trivial cases on model training.

Fig. 6 shows that the proposed method results above 80% on all word overlap rate ranges in the VNPC corpus. For the vnPara corpus, the proposed method's result is below 80% for sentence pairs with a word overlap rate of 0.3 or less. In the word overlap rate range [0.1; 0.2), the proposed method

TABLE VII. Evaluation Results of Different Methods on the vnPara Corpus

Method	Accuracy (%)	F1 score (%)
vnPara [4]	89.10	86.70
Siamese LSTM [9]	65.64	64.29
BERT	73.14	73.56
Our method (using BERT)		
Feature vector (BERT) + Semantic vector	94.12	94.28
Feature vector (BERT) + POS vector	72.45	72.22
Feature vector (BERT) + Semantic vector + POS vector	**94.27**	**94.38**
XLM-R	74.57	75.22
Our method (using XLM-R)		
Feature vector (XLM-R) + Semantic vector	93.58	93.76
Feature vector (XLM-R) + POS vector	75.12	75.51
Feature vector (XLM-R) + Semantic vector + POS vector	**93.67**	**93.85**
PhoBERT	76.33	75.80
Our method (using PhoBERT)		
Feature vector (PhoBERT) + Semantic vector	94.71	94.83
Feature vector (PhoBERT) + POS vector	75.83	75.20
Feature vector (PhoBERT) + Semantic vector + POS vector	**94.86**	**94.97**

TABLE VIII. Evaluation Results of Different Methods on the VNPC Corpus

Method	Accuracy (%)	F1 score (%)
Matching duplicate phrases and similar words [5]	87.68	Not available
Siamese LSTM [9]	65.64	64.29
BERT	86.85	92.77
Our method (using BERT)		
Feature vector (BERT) + Semantic vector	86.72	92.74
Feature vector (BERT) + POS vector	86.14	92.37
Feature vector (BERT) + Semantic vector + POS vector	**87.05**	**92.90**
XLM-R	86.61	92.65
Our method (using XLM-R)		
Feature vector (XLM-R) + Semantic vector	86.80	92.77
Feature vector (XLM-R) + POS vector	87.28	93.01
Feature vector (XLM-R) + Semantic vector + POS vector	**87.70**	**93.30**
PhoBERT	86.97	92.64
Our method (using PhoBERT)		
Feature vector (PhoBERT) + Semantic vector	87.45	93.12
Feature vector (PhoBERT) + POS vector	86.39	92.25
Feature vector (PhoBERT) + Semantic vector + POS vector	**88.02**	**93.49**

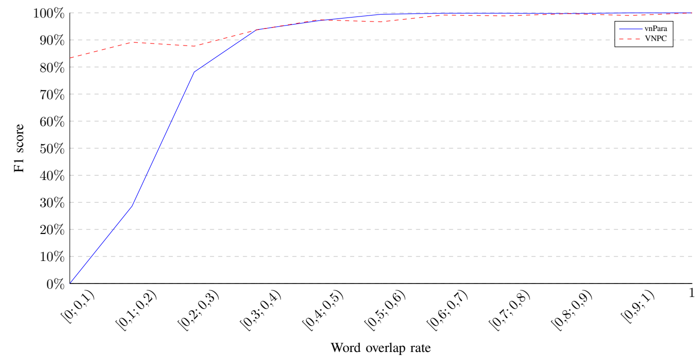

Fig. 6. F1 Score according to the Word Overlap Rate of Paraphrase Cases in vnPara and VNPC.

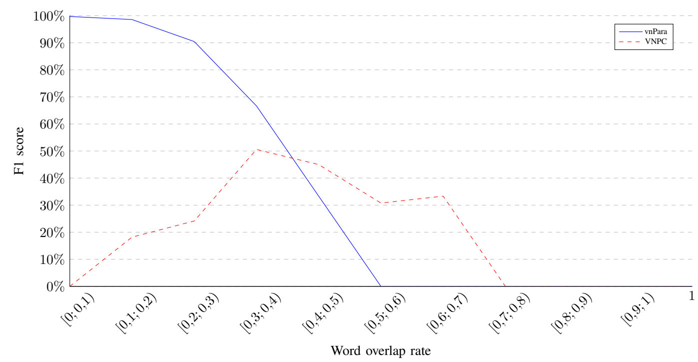

Fig. 7. F1 Score according to the Word Overlap Rate of Non-paraphrase Cases in vnPara and VNPC.

achieves F1 score of 28.57% for the vnPara corpus and 89.16% for the VNPC corpus.

In general, the F1 score is in Fig. 7 for the non-paraphrase cases of the VNPC is lower than vnPara corpus, due to the small number of non-paraphrase cases compared with the paraphrase cases in the VNPC corpus. The F1 score has a value of 0 in the range of overlap [0.7; 1] for the VNPC corpus and in [0.5; 1] for the vnPara corpus. This is because both corpora almost do not contain non-paraphrase cases in these two ranges. At the word overlap rate [0; 0.1), the test with the VNPC is 0% and the test with the vnPara reaches 99.71%.

To further demonstrate the universality of the proposed method's improvement over the pre-trained model, an experiment was performed on another corpus. Apart from the vnPara and the VNPC, almost no Vietnamese paraphrase corpora has been published. Therefore, the proposed model will be tested further on a Vietnamese translation of a well-known paraphrase corpus MSRP [41]. The evaluation results are shown in Table IX.

D. Discussion

The Siamese LSTM model produces mediocre results, because the training process of this model requires great corpora. For English, this model is trained with over 300,000 sentence pairs and achieves an accuracy rate of 82.29%. Meanwhile, existing Vietnamese paraphrase corpora contain only about 3,000 pairs of sentences.

TABLE IX. Evaluation Results on the Vietnamese-translated MSRP

Method	Accuracy (%)	F1 (%)
Siamese LSTM [9]	64.17	73.36
BERT	64.15	74.33
Our method (using BERT as feature vector)	**65.68**	**75.20**
XLM-R	65.89	76.06
Our method (using XLM-R as feature vector)	**66.42**	**76.09**
PhoBERT	59.90	67.10
Our method (using PhoBERT as feature vector)	**65.27**	**75.09**

The results show that our method achieves the best accuracy when using both semantic vector and POS vector. It outperforms the previous methods for Vietnamese paraphrase identification, also the Siamese LSTM model and the pre-trained model. The F1 score is much higher than the result of the pre-trained models in an experiment on VNPC. This proves that our method is more suitable for the Vietnamese paraphrase identification task that focuses more on paraphrase.

The number of duplicate sentences has a certain influence on the results of the proposed method. The number of duplicate sentences of VNPC is more than twice the number of duplicate sentences of vnPara. This means that the sentence diversity of vnPara is higher than that of VNPC, affecting the process of training deep learning models. This is also one of the reasons for our proposed method to achieve higher F1 score on the vnPara than on the VNPC when considering the paraphrase cases.

Fig. 6, 7 and the descriptions of these two figures partly show the importance of the non-trivial sentence pairs on the training process of the proposed method. The F1 score of our proposed method for paraphrase cases does not have great variation across all word overlap ranges for the VNPC, even though this corpus contains very few paraphrase sentence pairs in the range [0; 0.2) and [0.7; 1]. For the non-paraphrase cases having the word overlap rate is in the range [0.7; 1], our proposed method could not detect these cases on both vnPara and VNPC. Fig. 5 clearly shows the lack of non-trivial paraphrase cases on both corpora. Thus, it can be seen that the properties of the two corpora greatly affect the results that the proposed method achieves.

With testing on the Vietnamese-translated MSRP corpus, the results obtained from the proposed method are still higher than the results of the pre-trained models. Meanwhile, the results with the F1 score of our proposed method are much better. This shows that our proposed method still achieves higher results than the original pre-trained models when processing translated documents.

Although we achieve good results with our method, the model itself contains some disadvantages. First of all, the model requires big resources to operate, so it is not ready to work in practice. To build the semantic vector, the model depends much on the POS tagger. The mistakes of the POS tagger can entail the mistakes when building the semantic vector. The pre-trained models are used passively, not yet involved in the training process. Therefore, they have not been best exploited for this task.

V. Conclusion and Future Work

The paraphrase identification task is a crucial core task of several NLP tasks and applications. There are various studies for popular languages but a few for Vietnamese. The great challenge in the research for the Vietnamese paraphrase identification task is the lack of good and large corpora. The emergence of the pre-trained models enable us to propose a novel method that does not require large corpora for training but is still highly effective. The proposed method uses three vectors: feature vector achieved from pre-trained model, semantic vector constructed by using WordNet, POS vector represents the POS of words in a sentence. They are joined to form a sentence representations vector that contains rich context information. Explicit linguistic knowledge helps the method yield 94.97% F1-score on the VnPara corpus and 93.49% F1-score on the VNPC corpus, which is better than the pre-trained models for the paraphrase identification task in Vietnamese. These results also show that using a pre-trained model is a feasible way for studies of text similarity as well as other NLP tasks in resource-poor languages such as Vietnamese.

Although the method proposed in this paper achieves positive results, we realize that there are still potential improvements to achieve better results. We plan to fine-tune the pre-trained models in the training process to make the pre-trained models learn information from the input samples to have better sentence representation vectors. Using linguistic knowledge has proved to be effective. However, the resources for the proposed method to work are quite high. Hence, we need to create a method that uses fewer resources but still guarantees high accuracy rates.

Whereas the proposed method can solve the corpora lacking problem for deep learning, it is still necessary to have Vietnamese paraphrase corpora for fine-tuning, improvement, or evaluation. Meanwhile, the two existing Vietnamese paraphrase corpora still have some shortcomings such as class imbalance, the lack of non-trivial instances, and various duplicate sentences, etc. Therefore, the need to construct good-quality Vietnamese paraphrase corpora remains as pressing as ever.

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Optimized Design of Decoder 2 to 4, 3 to 8 and n to 2^n using Reversible Gates

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Abstract—**The design of low consumption CMOS circuits, nanotechnologies and quantum computing has becomed more attached to the reversible logic. A set of gates have been recently exploited in reversible computer science for the design of certain circuits. Among them, we find the decoders. In this paper we have exploited a recent study making the design of the decoder 2 to 4, 3 to 8, and n to 2^n, our work aims to enhance the previous designs , by replacing some reversible gates by others while maintaining their functionality and improving their performance criteria namely the number of gates (CG), number of garbage outputs (NGO), number of constant inputs(NCI), Quantum cost (QC) and hardware complexity (HC), compared to our study of the base and other recent studies from which we have obtained remarkable results.**

Keywords*—*Decoder 2to4; Decoder 3to8; Decoder n to2^n; Number of Gates (CG); Number of Garbage Output (NGO); Number of Constant Inputs (NCI); Quantum Cost (QC); Hardware Complexity (HC)

I. Introduction

The energy consumed in the circuits presents a major problem revealed in many research studies that are in progress to design low power devices. The loss of energy in static and dynamic electricity consumption within a chip generates thermal dissipation. Moreover, referring to the Landauer principle [1], heat occurs due to the loss of information in any irreversible circuit. The higher the number of information losses, the greater the heat dissipation. In irreversible circuits from the output vector, one cannot uniquely deduce the associated input vector which results in a loss of information which in turn generates a heat dissipation of KTln2Joules by bit loss, where K is the Boltzmann constant and T is the absolute temperature. The amount of heat loss seems small, but it will be large when a circuit contains a good amount of information loss. Bennett [2] in his research has proven that these heat generation problems can be resolved as long as the circuits could be designed with reversibility. There is no loss of information in the reversible circuits, and therefore a minimum amount of power dissipation. Today the need of reversible computing is important. Reversible computation is performed by reversible circuits. A quantum computer is quantum network composed of quantum logic gates; It has applications in many research areas such as Low Power Complementary Metal Oxide Semiconductor (CMOS) design, quantum computing, etc. All quantum gates are reversible gates and therefore quantum computing is one of the ways to design low power circuits. There is a one-to-one mapping of input-output model in all quantum gates. Reversible circuits are those circuits whose outputs can be decided from the input template. quantum cost. The pattern of quantum circuit design is to minimize the amount of waste and reduce the quantum cost.

On the other hand [21-23] the decrease in energy dissipated at the end of unused bits because heat is directly related to less garbage outputs.

This paper will be organized as follows:

the 2^nd section presents the reversible gates and their performance criteria, namely the quantum cost deduced from the associated quantum implementation, and the hardware complexity.

In the 3^rd section, we exploit a design of each decoder 2 to 4, 3 to 8, and n to 2^n from a recent article [13] we modify and show their associated performance criteria. To compare our new designs, we expose several designs from previous studies for comparison against our new designs of each decoder in terms of the 5 performance criteria CG, NGO; NCI, QC, and HC.

In the 4^th section, we will present our design of the decoder 2 to 4, 3 to 8 and n to 2^n and display 5 performance criteria while calculating the percentages of improvement obtained. finally, in the 5^th section a conclusion and perspectives.

II. The Reversible Gates Concerned by the Study and their Performance Criteria

In this section we will define the performance criteria concerned by this article which are in total 5.

A. Performance Criteria:

1) Number of Gates (CG): The number of gates required to make a circuit [3].

2) Number of Garbage Outputs (NGO): The unused or unwanted logic outputs of the reversible gate maintain in the output lines to make the circuit reversible [3].

3) Number of Constant Inputs (NCI): Number of inputs that must be remain constant at 0 or 1 to integrate the given logic function [3].

4) Quantum Cost(QC): The QC is calculated by counting the number of a one input–output and two input–output reversible gates used in realizing a circuit [4,5]. The QC of a one input–output and two input–output reversible gates is realized to be 1.

5) Hardware Complexity (HC): The number of fundamental operations (Ex-OR, AND,NO, etc.) required to make the circuit. actually, a constant complexity is supposed for each fundamental operation of the circuit, such as α for Ex-OR, β for AND, δ for NOT, etc. Eventually, the entire number of operations is calculated in terms of α, β, and δ [6].

In this section we will present the reversible gates that are concerned by this paper by showing their performance criteria, namely the quantum cost that we deduce directly from the quantum implementation, and its hardware complexity.

B. Reversible Gates

1) NOT Gate: A reversible gate 1 * 1 having as inputs A and as outputs P = A' the quantum cost of the gate NOT gate is worth QC = 0, its Hardware complexity is worth HC = 1α [3]

2) Feyman Gate FG: A reversible gate 2 * 2 having as inputs A and B and as outputs P = A and Q = A $\bigoplus$ B the quantum cost of the gate FG is worth QC = 1, its Hardware complexity is worth HC = 1α [3]

3) Double Feyman Gate F2G: A reversible gate 3 * 3 having as inputs A , B and C as outputs P = A and Q = A $\bigoplus$ B R= A $\bigoplus$ C the quantum cost of the gate FG is worth QC = 2, its Hardware complexity is worth HC = 2α [3]

4) Fredkin Gate FRG : A reversible gate 3 * 3 figure 1.31 having as inputs A, B and C and as outputs P = A, Q = A'B $\bigoplus$ AC and R = A'C $\bigoplus$ AB the quantum cost of the FRG gate is equal to QC = 2, its Hardware complexity is equal to HC = 2 α + 4 β + 1 δ [3]

5) Peres Gate PG : A reversible gate 3 * 3 figure 1.35 having as inputs A, B and C and as outputs P = A, Q = A $\bigoplus$ and R = AB $\bigoplus$ C the quantum cost of the gate PG is equal to QC = 4, its Hardware complexity is worth HC = 2 α + 1 β [7]

6) RI Gate : A reversible gate 3 * 3 having for inputs A, B and C as outputs P = B, Q = AB'+BC C and R = AB $\bigoplus$ C the quantum cost of the RI gate is equal to QC = 4, its Hardware complexity is worth HC = 1 α+3β+1δ [8]

7) HLGate : A reversible gate 4 * 4 having as inputs A, B, C and D as outputs P = AB'$\bigoplus$B'C$\bigoplus$BD', Q = AB$\bigoplus$B'C$\bigoplus$BD, R = A'B$\bigoplus$B'C$\bigoplus$BD and S = AB'$\bigoplus$BC$\bigoplus$B'D the quantum cost of the HL gate is equal to QC = 7, its Hardware complexity is worth HC = 7 α + 9 β+3δ [9]

8) NKHD Gate : A reversible gate 6 * 6 having as inputs A, B, C, D,E and F as outputs P = A, Q = BE$\bigoplus$B'(A$\bigoplus$C) , R = B'E$\bigoplus$B(A$\bigoplus$C), S = B$\bigoplus$B'E$\bigoplus$B(A$\bigoplus$C) , T=B$\bigoplus$B'E$\bigoplus$B(A$\bigoplus$C)$\bigoplus$(A$\bigoplus$D) and U =B$\bigoplus$F the quantum cost of the NKHD gate is equal to QC = 11 and its Hardware complexity is equal to HC = 6 α + 4 β+1δ [10]

9) TR Gate : A reversible gate 3 * 3 having for inputs A, B and C as outputs P = A, Q = A $\bigoplus$ B, R = AB' $\bigoplus$ C, S = AB $\bigoplus$ C $bigoplus$ D the quantum cost of the TR gate is equal to QC = 4 and its Hardware complexity is equal to HC = 2 α + 1 β+1 δ [20]

10)DVSM Gate : A reversible gate 4 * 4 having for inputs A, B, C and D as outputs P = AB$\bigoplus$A'C, Q = AB' $\bigoplus$ A'C, R = A'B $\bigoplus$ AC'and S= D$\bigoplus$AC$\bigoplus$A'B' the quantum cost of the TR gate is equal to QC = 11 and its Hardware complexity is equal to HC = 5 α + 7 β+3 δ [11]

11)MFRG1 Gate : A reversible gate 3 * 3 having for inputs A, B and C as outputs P = A, Q = A'B $\bigoplus$ AC', R = A'C $\bigoplus$ AB, the quantum cost of the TR gate is equal to QC = 4 and its Hardware complexity is equal to HC = 2 α + 4 β+2 δ [12]

12)MFRG2 Gate : A reversible gate 3 * 3 having for inputs A, B and C as outputs P = A', Q = A'B $\bigoplus$ AC, R = A'C $\bigoplus$ AB, the quantum cost of the TR gate is equal to QC = 4 and its Hardware complexity is equal to HC = 2 α + 4 β+1 δ [12]

13) OM Gate : A reversible gate 3 * 3 having for inputs A, Band C as outputs P = A, Q = AB $\bigoplus$ C', R = A'B $\bigoplus$ C',the quantum cost of the OM gate is not mentioned in the literature and its hardware complexity is HC = 2 α + 2 β+2 δ[13]

14) SOM Gate : A reversible gate 4 *4 having for inputs A, B, C and D as outputs P = AB$\bigoplus$C$\bigoplus$D, Q = AB' $\bigoplus$ C, R = A'B $\bigoplus$ C$\bigoplus$D S=A'B'$\bigoplus$C$\bigoplus$D,the quantum cost of the SOM gate is not mentioned in the literature and its hardware complexity is HC = 5 α + 4 β+2 δ[13]

15) UM Gate : A reversible gate 6 *6 having for inputs A, B, C ,D,E and F as outputs P = A, Q = AB $\bigoplus$ C', R = A'B $\bigoplus$ C' S=A$\bigoplus$D, T=DE$\bigoplus$F' and U=D'E$\bigoplus$F' the quantum cost of the SOM gate is not mentioned in the literature and its hardware complexity is HC = 5 α + 4 β+4 δ[13]

16)RD Gate : A reversible gate 4 *4 having for inputs A, B, C and D as outputs P = AB$\bigoplus$D, Q = (A+B)' $\bigoplus$ D, R = (A+B') $\bigoplus$ C$\bigoplus$D S=AB'$\bigoplus$D, the quantum cost of the RD gate is 8 and its hardware complexity is HC = 5 α + 2 β+2 δ

III. Related Work

In this section, we will present the recent studies of the decoder design :

A. Decoder 2 to 4

1) Design1 & Design2: In 2020 Gunajit Kalita [13] proposed 2 decoders designs 2 to 4 as shown in Fig. 1 and 2, respectively .

* Design1: The author has used the reversible gate SOM by assigning to the third and fourth input the value 0 so we have CG = 1, NGO = 0, NCI = 2, QC = not mentioned and HC =5 α + 4 β+2 δ

* Design2 : The author has used the reversible gate Um by assigning the third and the sixth input the value 1 and at the fourth input the value A and at the fifth input the value B 'so we have CG = 1, NGO = 2, NCI = 4, QC = not mentioned and HC =6 α + 4 β+4 δ

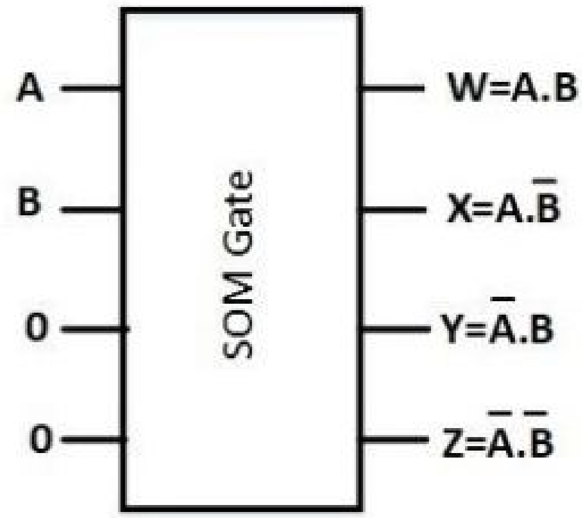

Fig. 1. Design used SOM Reversible Gate.

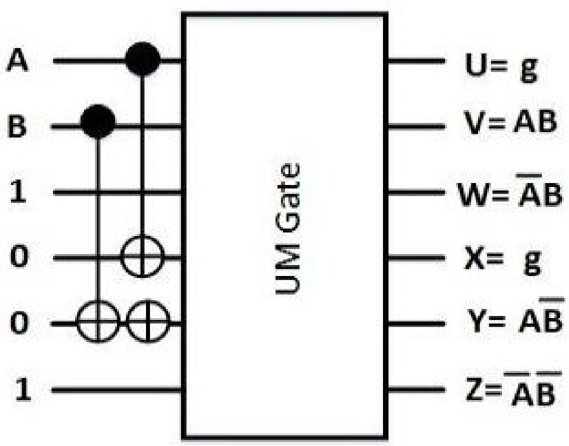

Fig. 2. Design used UM Reversible Gate.

2) Design3 and Design4: In 2013 Lafifa Jamal[9] proposed 2 decoder designs 2 to 4 as shown in Fig. 3 and 4, respectively .

* Design 3: The author has used 1 reversible gate FG and 2 reversible gates FRG so we have CG = 3, NGO = 1, NCI = 3, QC = 11 and HC =5 α + 8 β+2 δ

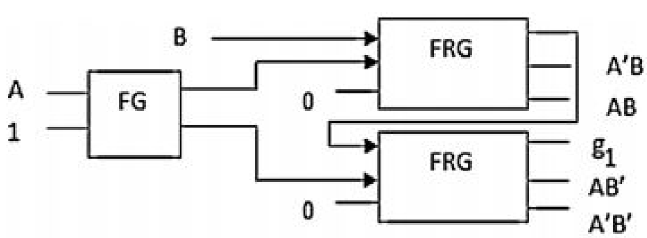

Fig. 3. Design used FG and 2 FRG Reversible Gates.

* Design4: The author has used 1 reversible gate HL so we have CG = 1, NGO = 0, NCI = 2, QC = 7 and HC =7 α + 9 β+3 δ

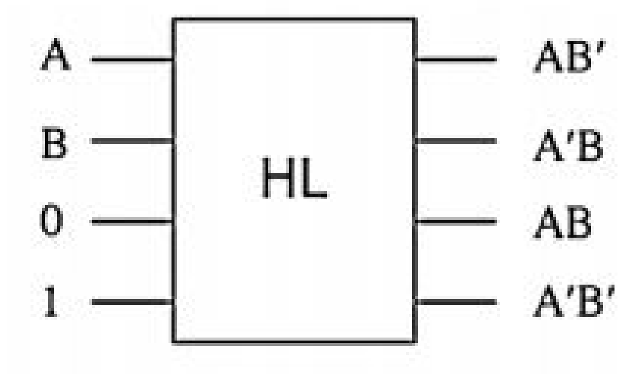

Fig. 4. Design used HL Reversible Gate.

3) Design5: In 2012 Ravish Aradhya HV [14]proposed 1 decoder designs 2 to 4 as shown in Fig. 5 by using 3 reversible gates of the FRG concerning its performance criteria we have CG = 3, NGO = 2, NCI = 3, QC = 15 and HC=6 α + 24 β+3 δ

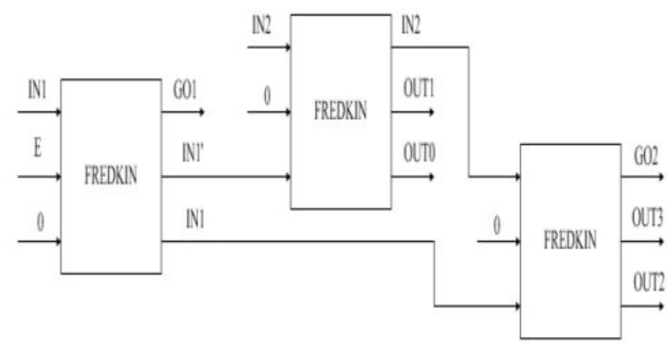

Fig. 5. Design used 3 FRG Reversible Gates.

4) Design6: In 2017 Nazma Tara [10] proposed 1 design of decoder 2 to 4 as shown in Fig. 6. by using 1 reversible gate of the NKHD by assigning to the third input the value 1 and to the fourth, fifth and sixth input the value 0 and concerning its performance criteria we have CG = 1, NGO = 2, NCI = 4, QC = 11 and HC = 6α + 4 β+1 δ

5) Design7: In 2018 Vandana Shukla [11]proposed 1 design of decoder 2 to 4 as shown in Fig. 7. by using 1 reversible gate of the DVSM by assigning to the third and the fourth input the value 0 and concerning its performance criteria we have CG = 1, NGO = 0, NCI = 2, QC = 11 and HC = 5α + 7 β+3 δ

6) Design8: In 2018 G. Greekanth [15] proposed 1 design of decoder 2 to 4 as shown in Fig. 8. by using 2 reversible NOT gates, 2 reversible gates RI by assigning to the 2 third inputs for each the value 0 and concerning its performance criteria we have CG = 2, NGO = 2, NCI = 2, QC = 8 and HC = 2α + 6 β+4 δ

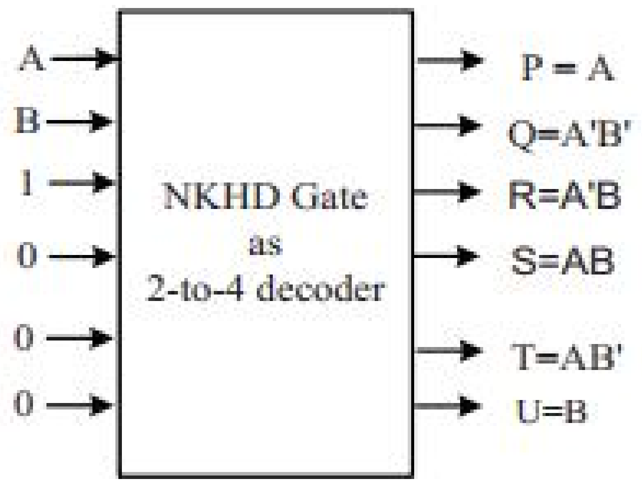

Fig. 6. Design used NKHD Reversible Gate.

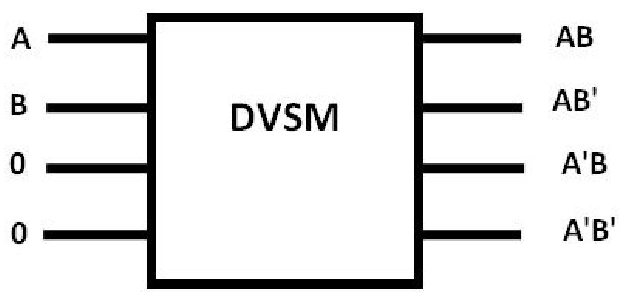

Fig. 7. Design used DVSM Reversible Gate.

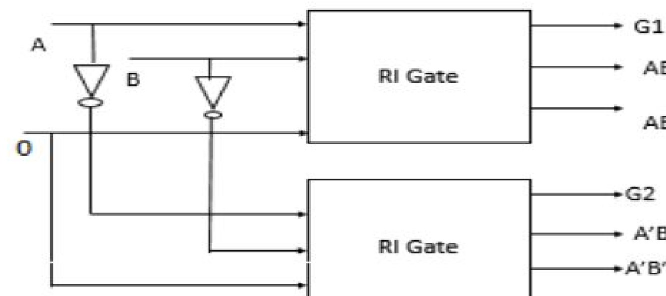

Fig. 8. Design used 2 RI Reversible Gate.

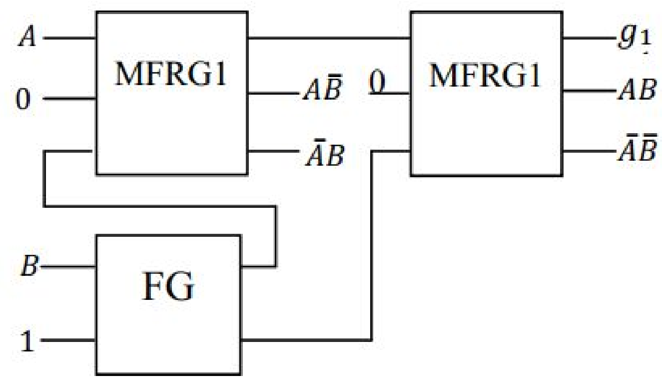

Fig. 9. Design used FG and 2 MFRG1 Reversible Gates.

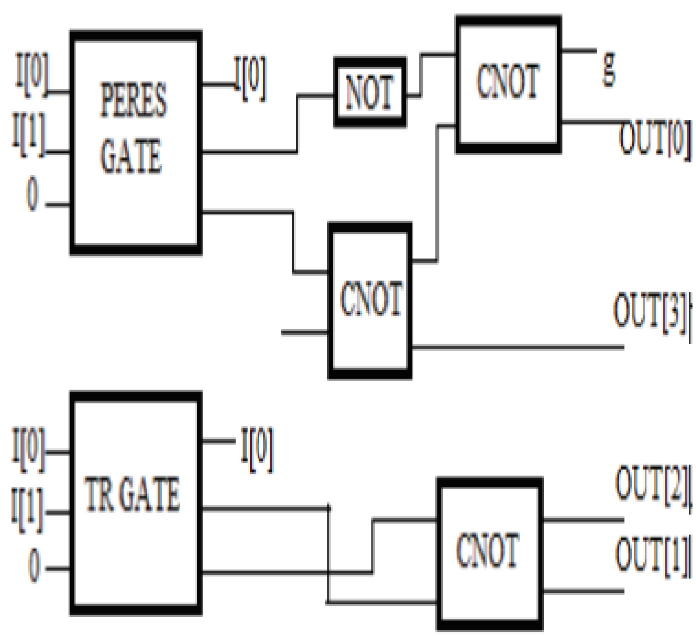

Fig. 10. Design used 3 Reversible Gate CNOT, 1 Reversible NOT Gate, 1 Reversible Gate PG and 1 Reversible Gate TR.

7) *Design9:* In 2012 Md. Selim Al Mamun [12] proposed a design of decoder 2 to 4 as shown in Fig. 9 by using 1 reversible gate FG and 2 reversible gates MFRG1 whose performance criteria are as follows: CG = 3, NGO = 1, NCI = 3, QC = 9 and HC = 5α + 8 β+4 δ

8) *Design10:* In 2017 Gopi Chand Naguboina [16] proposed a design of decoder 2 to 4 as shown in Fig. 10 by using 3 reversible gate CNOT, 1 reversible NOT gate, 1 reversible gate PG and 1 reversible gate TR whose performance criteria are as follows: CG = 6, NGO = 3 , NCI = 3, QC = 11 and HC = 7α + 2 β+2 δ

9) *Design11:* In 2019 Heranmoy Maity [17] proposed a design of decoder 2 to 4 as shown in Fig. 11 by using 1 reversible gate PG, whose performance criteria are as follows: CG = 1, NGO = 0, NCI = 2, QC = 9 and HC =7α + 1 β

10) *Design12:* In 2013 Md. Shamsujjoha [18] proposed a design of decoder 2 to 4 as shown in Fig. 12 by using 1 reversible gate F2G and 2 reversible gates FRG whose performance criteria are as follows: CG = 3, NGO = 2, NCI = 4, QC = 12 and HC =6α + 8 β+2δ

In the following we expose the recent designs of the 3 to 8 decoder:

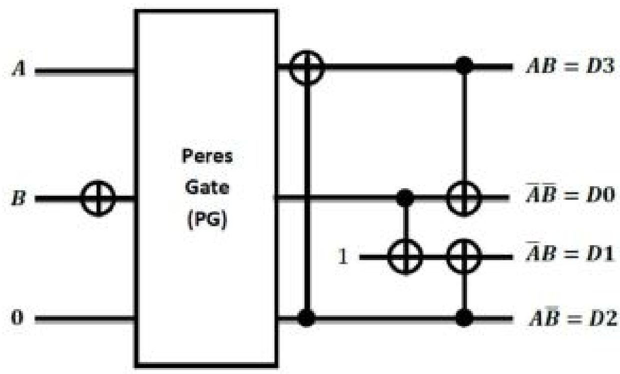

Fig. 11. Design used 1 PG Reversible Gate.

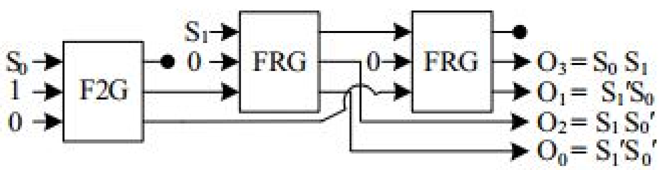

Fig. 12. Design used 1 F2G and 2 FRG Reversible Gates.

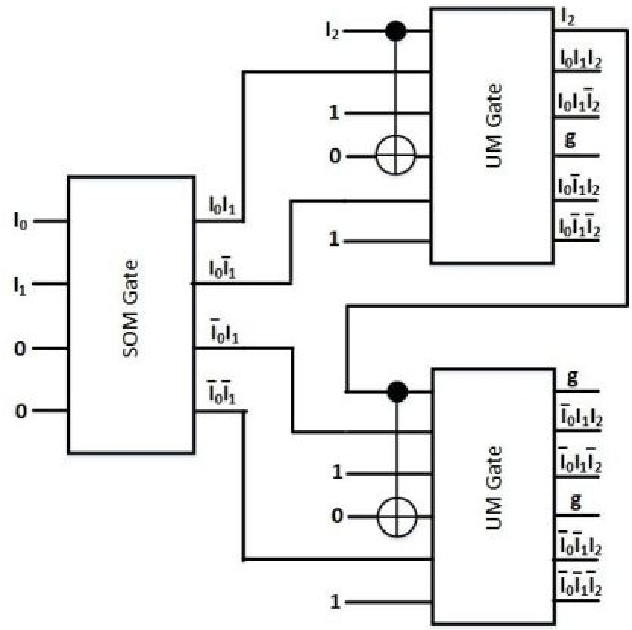

Fig. 13. Design used 1 SOM and 2 UM Reversible Gates.

B. Decoder 3to8

1) Design1 & Design2: In 2020 Gunajit Kalita [13]proposed 2 decoders designs 3 to 8

* design1 : The author has used 1 reversible gate SOM by assigning to the third and fourth input the value 0 and 2 reversible gates UM each of which by assigning to the third and sixth input the value 1 its performance criteria are as follows: CG = 3, NGO = 3, NCI = 8, QC = not mentioned in the literature and HC =17 α + 12 β+10 δ taking into account the 2 CNOT used as shown in Fig. 13.

* design2 : The author had used 1 reversible gate SOM by assigning to the third and fourth input the value 0 and 4 reversible gates OM each of which by assigning to the third input the value 1 its performance criteria are as follows: CG = 5, NGO = 1, NCI = 6, QC = not mentioned in the literature and HC =13 α + 12 β+10 δ as shown in Fig. 14.

2) Design3 & Design4: In 2013 Lafifa Jamal[9] proposed 2 decoder designs 3 to 8

* design 3 : The author has used 1 reversible gate FG by assigning the second input the value 1 and the rest of 6 reversible gates FRG by assigning the third input the value 0 so we have CG = 7, NGO = 2, NCI = 7, QC = 31 and HC =13 α + 24 β+6 δ as shown in Fig. 15.

The 2 to 4 reversible decoder circuit is equivalent to fig3

* design4 : Using 1 reversible gate HL by assigning the third input the value 0 and the fourth input the value 1 and the rest of 4 reversible gates FRG by assigning the third input the value 0 so we have CG = 5, NGO = 1, NCI = 6, QC = 27 and HC =15 α + 25 β+7 δ as shown in Fig. 16.

The 2 to 4 reversible decoder circuit is equivalent to fig4.

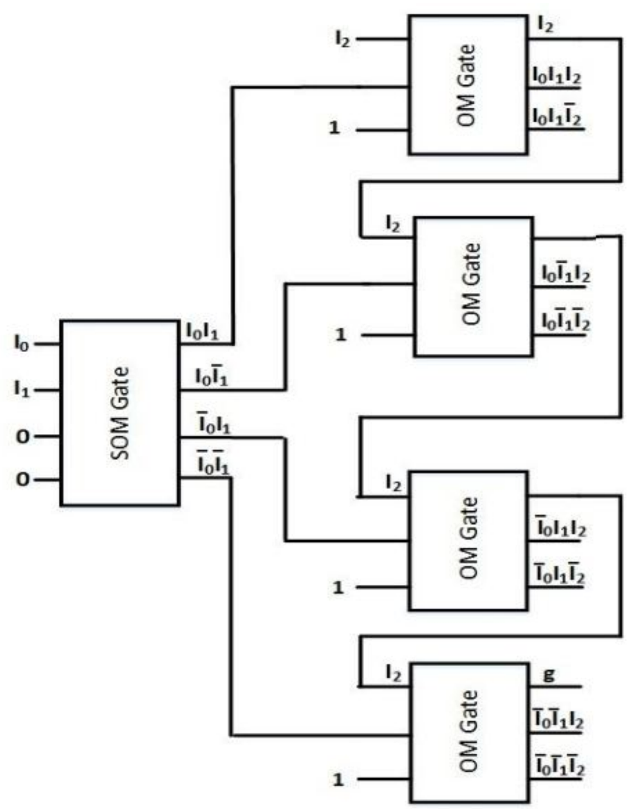

Fig. 14. Design used 1 SOM and 4 OM Reversible Gates.

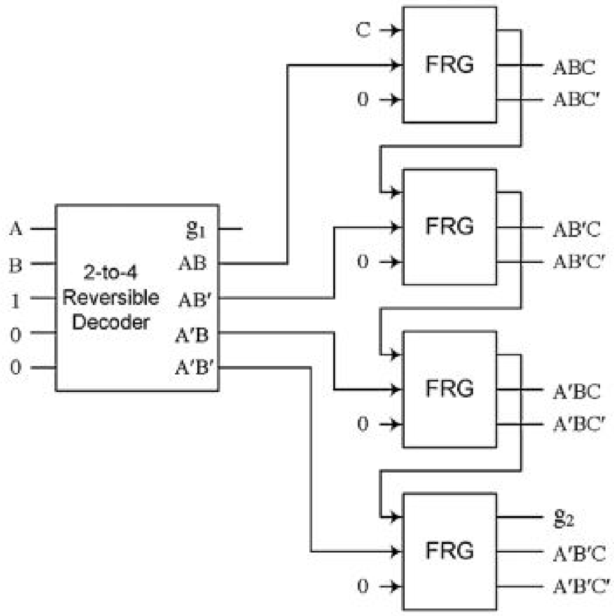

Fig. 15. Design used 1 FG and 6 FRG Reversible Gates.

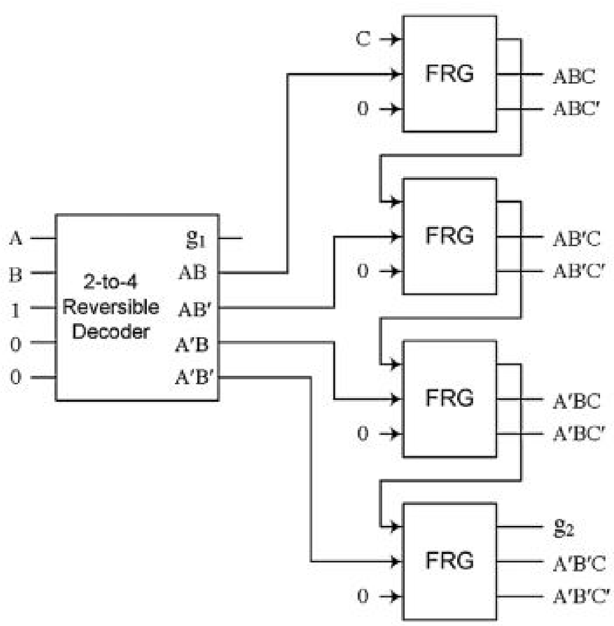

Fig. 16. Design used 1 HL and 4 FRG Reversible Gates.

3) Design5: In 2012 Ravish Aradhya HV [14] proposed 1 decoder designs 3 to 8 by using 7 reversible gates of the FRG, concerning one reversible FRG gate by assigning its second input to the value 1 and the third input to the value 0 and for the rest of the 6 FRG reversible gates, the value 0 is assigned to the third input by concerning its performance criteria we have CG = 7, NGO = 2, NCI = 8, QC = 35 and HC=14 α + 28 β+7 δ as shown in Fig. 17.

4) Design6: In 2017 Nazma Tara [10]proposed a design of the decoder 3 to 8 using an NKHD reversible gate by assigning

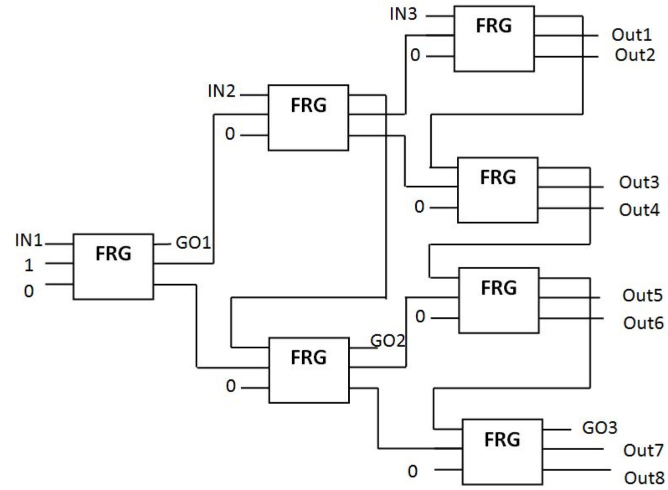

Fig. 17. Design used 7 FRG Reversible Gates.

to the third input the value 1 and to the fourth, fifth and sixth input the value 0 and 4 FRG reversible gates assigning to the third input for each the value 0 concerning its performance criteria we have CG = 5, NGO = 3, NCI = 8, QC = 31 and HC=14 α + 20β+5 δ as shown in Fig. 18.

Fig. 18 shows the 2 to 4 reversible decoder circuit equivalent design shown in Fig. 6.

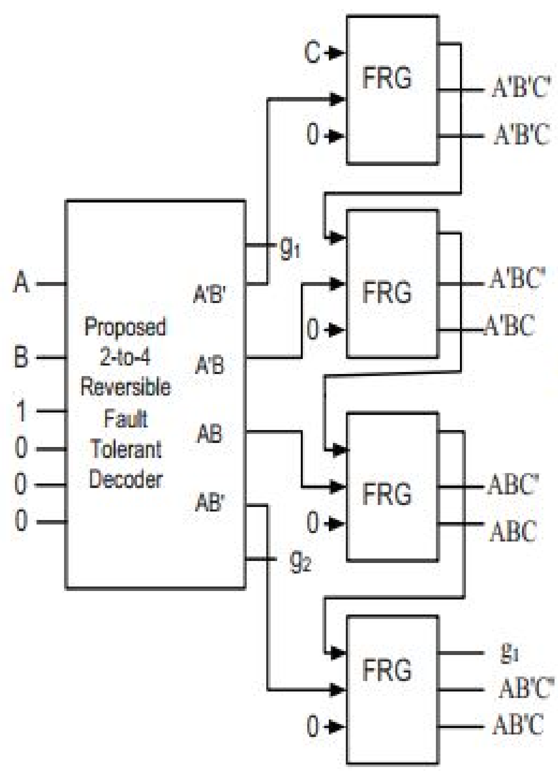

Fig. 18. Design used 7 FRG Reversible Gates.

5) Design7: In 2018 Vandana Shukla [11] proposed a design of the decoder 3 to 8 using an DVSM reversible gate by assigning to the third and the fourth input the value 1 and for 4 FRG reversible gates assigning to the third input for each the value 0 concerning its performance criteria we have CG = 5, NGO = 1, NCI = 6, QC = 31 and HC=13 α + 23β+7 δ as shown in Fig. 19.

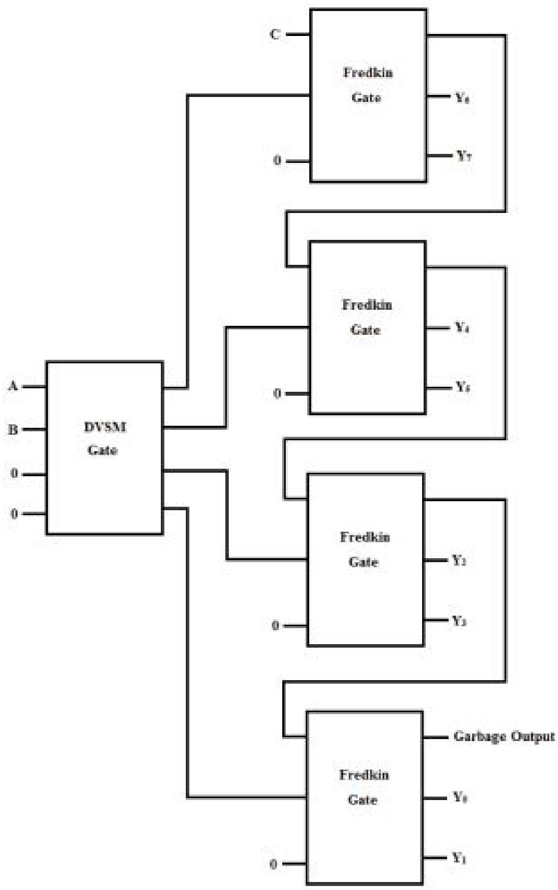

Fig. 19. Design used DVSM and 4 FRG Reversible Gates.

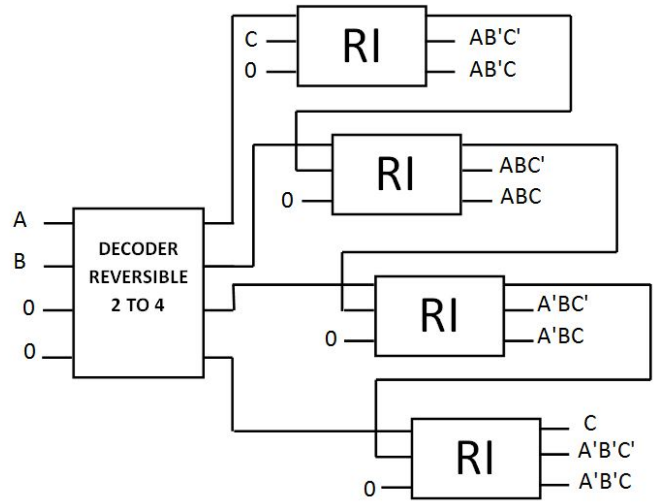

Fig. 20. Design used 6 RI Reversible Gates.

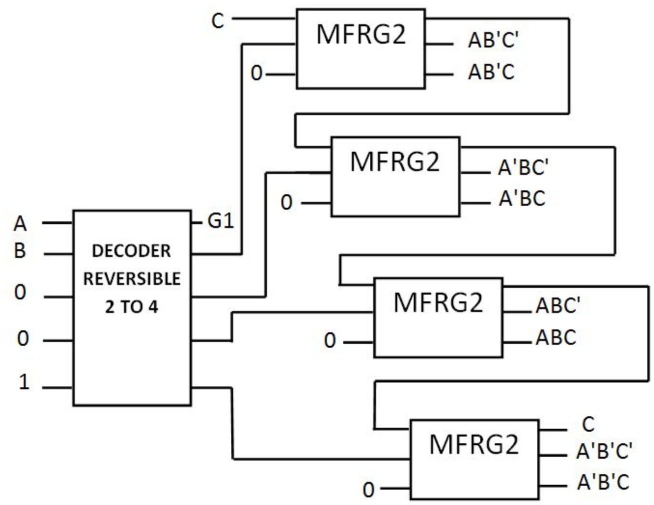

Fig. 21. Design used 1FG 2 MFRG1 and 4 MFRG2.

6) Design8: In 2018 G.Sreekanth [15] proposed a design of the decoder 3 to 8 using 6 RI reversible gate by assigning to the third input the value 0 for all gates concerning its performance criteria we have CG = 6, NGO = 3, NCI = 6, QC = 24 and HC=6 α + 18β+8δ as shown in Fig. 20. taking into account 2 NOT used

The 2 to 4 reversible decoder circuit is equivalent to Fig. 8.

7) Design9: in 2012 Md. Selim Al Mamun [12]proposed a design of decoder 3 to 8 using 1 reversible gate FG and 2 reversible gates MFRG1 and 4 reversible MFGR2 by assigning to the third input the value 0 , whose performance criteria are as follows: CG = 7, NGO = 2, NCI = 7, QC = 29 and HC = 13α + 24 β+9 δ as shown in Fig. 21.

The 2 to 4 reversible decoder circuit is equivalent to Fig. 9.

8) Design10: In 2016 Anish Kumar Saha [19] proposed a design of decoder 3 to 8 whose performance criteria are as follows: CG = 10, NGO = 3, NCI = 8, QC = 50.

9) Design11: (fig20) in 2017 Gopi Chand Naguboina[16] proposed a design of decoder 2 to 4 using 3 reversible gate FG, 1 reversible NOT gate, 1 reversible gate PG and 1 reversible gate TR and 4 FRG reversible by assigning to the second input the value 0 gates whose performance criteria are as follows: CG = 10, NGO = 3 , NCI = 7, QC = 31 and HC = 15α + 18 β+6 δ as shown in Fig. 22.

10) Design12: In 2013 Md. Shamsujjoha [18] proposed a design of decoder 3 to 8 using 1 F2G reversible gate and 6 FRG reversible gate, by assigning to the second input the value 0 gates whose performance criteria are as follows: CG = 10, NGO = 7 , NCI = 8, QC = 32 and HC = 14α + 24 β+6 δ as shown in Fig. 23.

C. Decoder n to 2^n

1) Design1 & Design2: In 2020 Gunajit Kalita [13]proposed 2 decoders designs n to 2^n

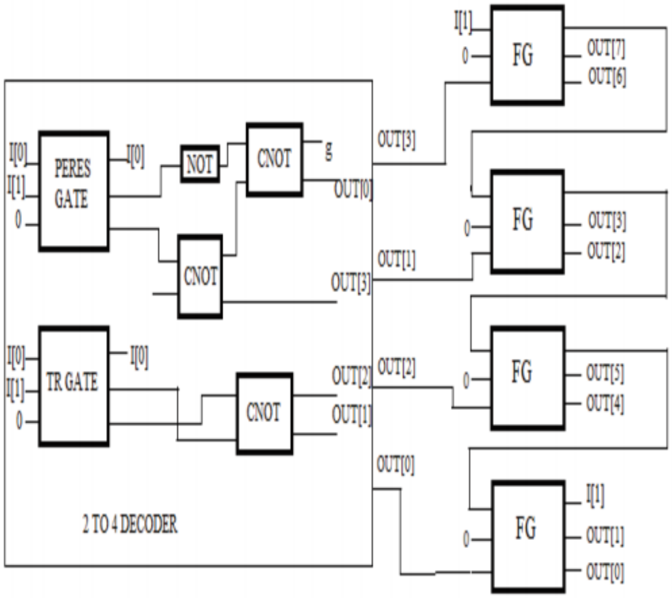

Fig. 22. Design used 3 Reversible Gate CNOT, 1 Reversible NOT Gate, 1Reversible Gate PG 1 Reversible Gate TR and 4 FRG.

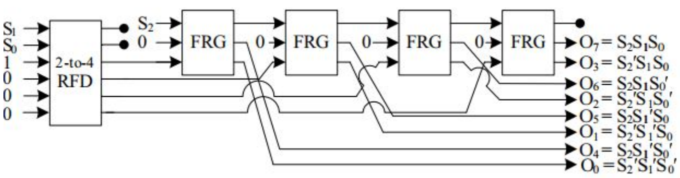

Fig. 23. Design used 1 f2G and 6FRG.

* design1 : To build the circuit of the decoder n to 2^n he used a reversible gate SOM and 2 reversible gates UM and assigning to each increment 2 reversible gates Um to each reversible gate UM previous as shown in Fig. 24.

Concerning the performance criteria we have CG = $(2^{n-1}-1)$ -1, NGO = $(2^{n-1}$+n-4), NCI = 32^{n-1}-4, QC not mentioned in the literature and HC = HC (SOM) + $(2^{n-1}$ -2) HC (UM) so HC=$(52^{n-1}$-5)α+$(42^{n-1}$-4)β+$(42^{n-1}$-6)δ taking into account the 2^{n-2} CNOT at each level of n

* design2 : To build the circuit of the decoder n to 2^n he used a reversible gate SOM and 4 reversible gates OM and assigning to each increment 2 reversible gates Um to each reversible gate OM previous as shown in Fig. 25. Concerning the performance criteria we have CG = (2^n)-3, NGO = (n-2), NCI = 2^n-2 ,QC not mentioned in the literature and HC = HC (SOM) + $(2^n$-4) HC (OM)= HC=$(2^{n+1}$-3)α+$(2^{n+1}$-4)β+(2^{n+1}-6)δ

2) Design3 & Design4: In 2013 Lafifa Jamal[9] proposed 2 decoder designs n to 2^n

* design 3 : To build the circuit of the decoder n to 2^n he used 1 reversible gate FG and 2 reversible gates FRG and assigning to each increment 2 reversible gates FRG to each reversible gate FRG previous as shown in Fig. 26.

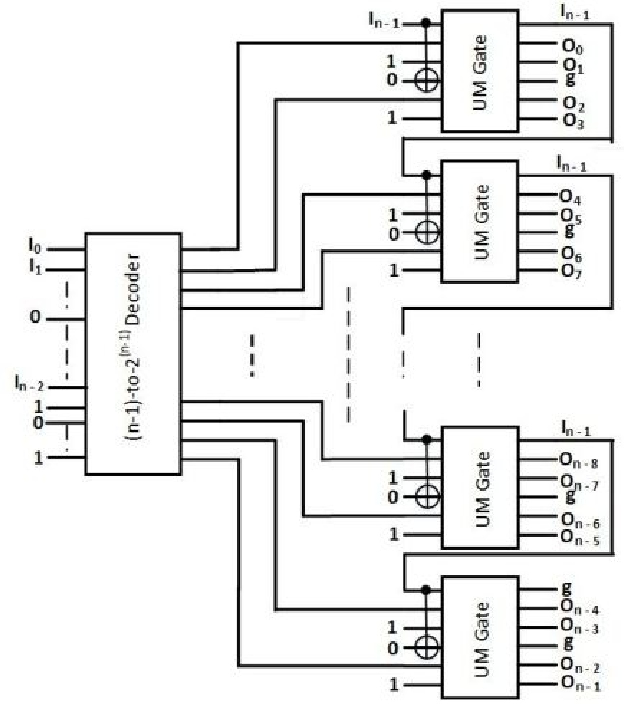

Fig. 24. Design Decoder n to 2^n used SOM and UM.

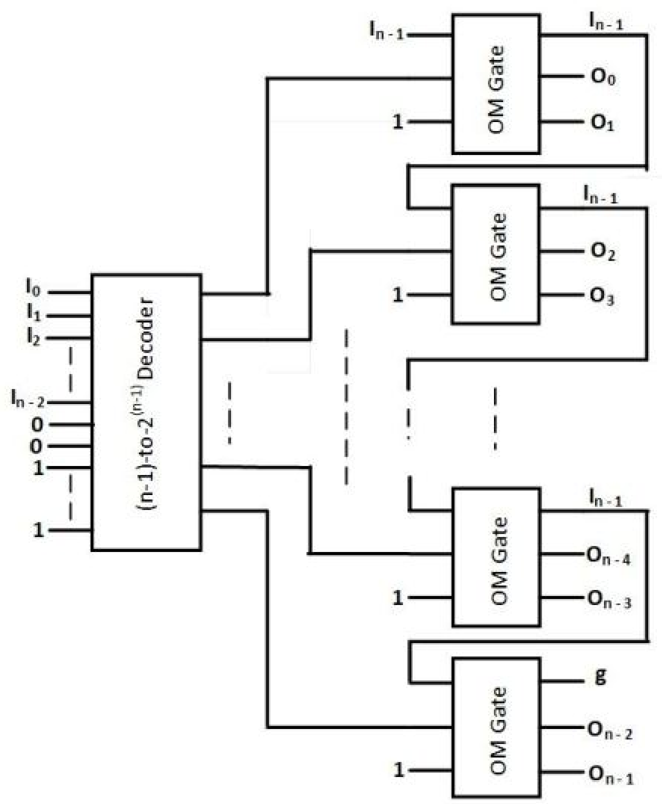

Fig. 25. Design Decoder n to 2^n used SOM and OM.

Concerning the performance criteria we have CG = (2^n) -1, NGO = (n-1), NCI =2^n -1 ,QC=5 2^n-9 and HC = HC (FG+2FRG) + (2^n-4) HC (FRG)= HC=(2^n+1-3)α+(2^n+2-8)β+(2^n-2)δ

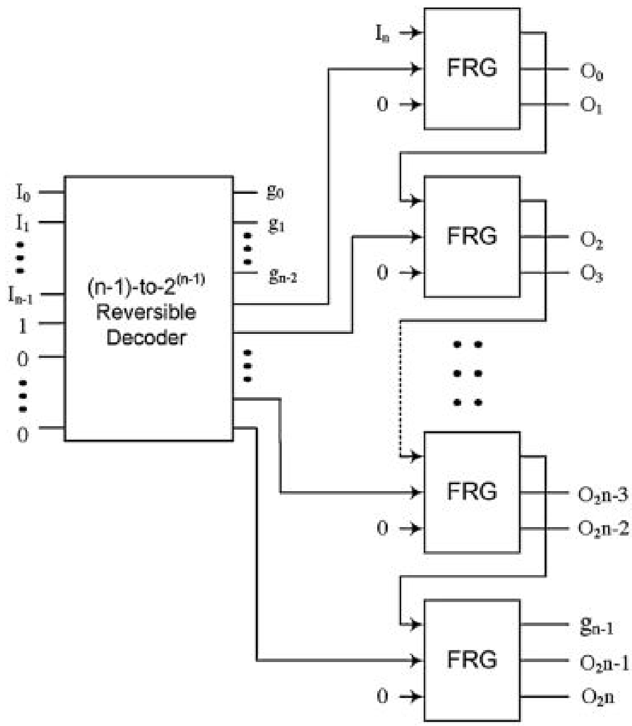

Fig. 26. Design Decoder n to 2^n used FG and FRG.

* design4: To build the circuit of the decoder n to 2^n he used 1 reversible gate HL and 4 reversible gates FRG and assigning to each increment 2 reversible gates FRG to each reversible gate FRG previous as shown in Fig. 27.

Concerning the performance criteria we have CG = (2^n)-3, NGO = (n-2), NCI = 2^n -2 ,QC=5 2^n-13 and HC = HC (HL) + (2^n-4) HC (FRG)= HC=(2^n+7)α+(2^{n+1}+9)β+(2^{n-1}+3)δ

3) Design5: In 2012 Ravish Aradhya HV [14]proposed a decoder designs n to 2^n used 3 reversible gate FRG and assigning to each increment 2 reversible gates FRG to each reversible gate FRG previous as shown in Fig. 28.

Concerning the performance criteria we have CG = (2^n) -1, NGO = (n), NCI = 2^n ,QC=5 2^n-5 and HC = HC (3FRG) + (2^n-4) HC (FRG)= HC=(2^{n+1}-2)α+(2^{n+2}-4)β+(2^n-1)δ

4) Design6: In 2017 Nazma Tara [10] proposed a decoder designs n to 2^n used 1 reversible gate NKHD and 2 reversible gates FRG and assigning to each increment 2 reversible gates FRG to each reversible gate FRG previous as shown in Fig. 29.

Concerning the performance criteria we have CG = (2^n)-3, NGO = n, NCI = 2^n ,QC=5 2^n-9 and HC = HC (NKHD) + (2 (n) -4) HC (FRG)= HC=(2^{n+1}-2)α+(2^{n+2}-12)β+(2^n-3)δ

5) Design7: In 2012 Md. Selim Al Mamun [12] a decoder designs n to 2^n used 1 reversible gate FG ,2 reversible gates MFRG1 and 2 reversible gates MFRG2 and assigning to each

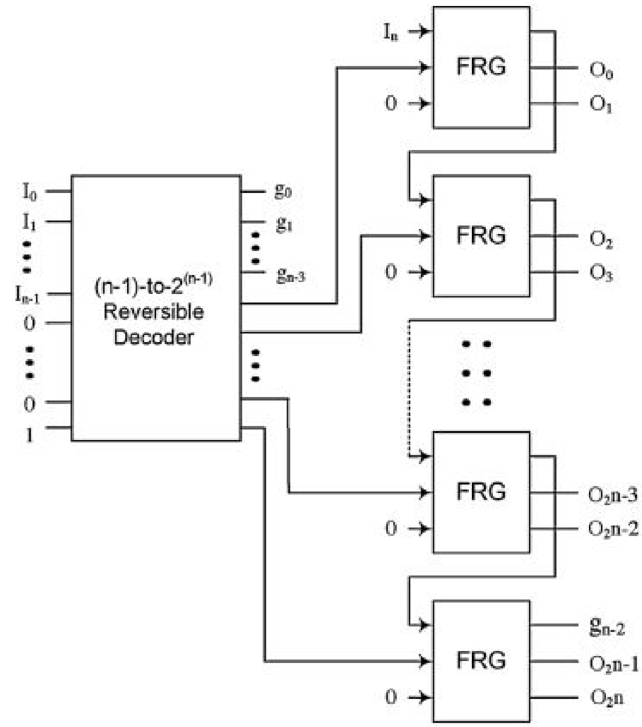

Fig. 27. Design Decoder n to 2^n used HL and FRG.

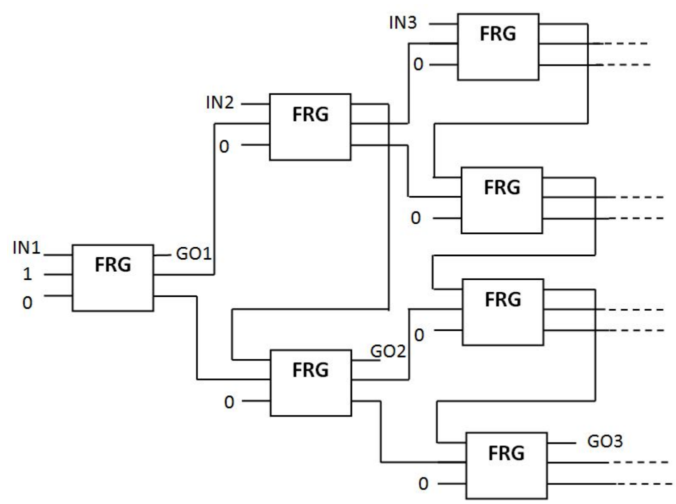

Fig. 28. Design Decoder n to 2^n using FRG.

increment 2 reversible gates MFRG2 to each reversible gate MFRG2 previous.

Concerning the performance criteria we have CG = (2^n)-1 NGO = n-1, NCI=2^n-1 ,QC=5$2^n$-11 and HC = HC (2MFRG1+FG) + (2^n -4) HC (MFRG2)= HC=(2^{n+1}-3)α+(2^{n+2}-8)β+$2^n\delta$

6) Design8: In 2016 Anish Kumar[19] proposed a decoder designs n to 2^n concerning the performance criteria we have CG = 10, NGO = n, NCI=2^n ,QC=6 2^n and HC = not mentioned in the literature.

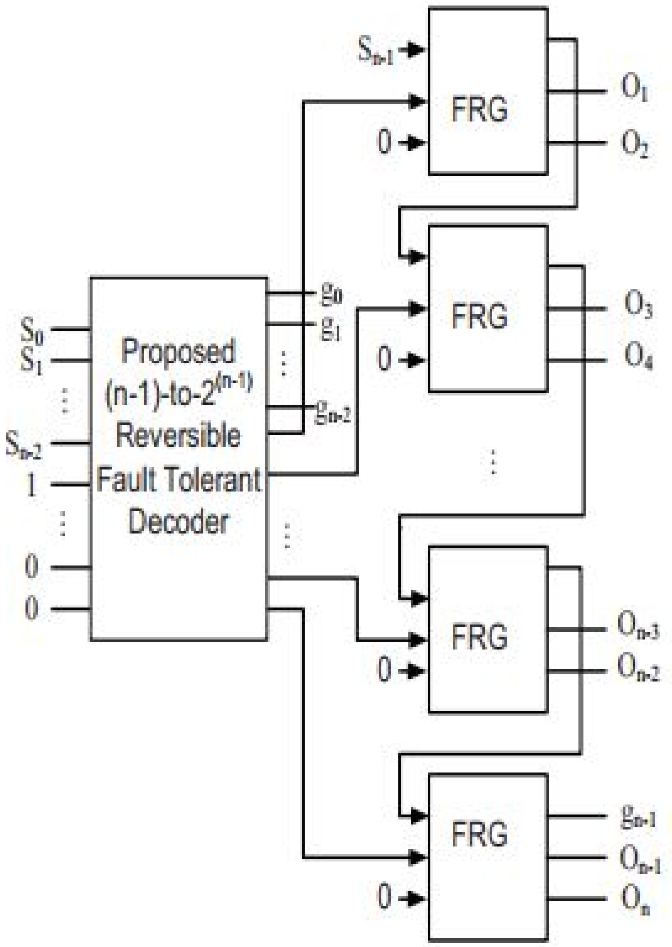

Fig. 29. Design Decoder n to 2^n used NKHD and FRG.

7) Design9: In 2013 Md. Shamsujjoha [18] proposed n to 2^n using 1 F2G reversible gate and 2 reversible gates FRG ,and assigning to each increment 2 reversible gates FRG to each reversible gate FRG previous as shown in Fig. 30. Concerning the performance criteria we have CG = (2^n)-1 NGO = n, NCI=2^n ,QC=5$2^n$ -8 and HC = HC (F2G) + (2^n-2) HC (FRG)= HC=(2^{n+1}-2)α+(2^{n+2}-8)β+(2^n-2)δ

Limitations of previous studies: We find in these previous studies a certain limitation in terms of less optimized performance criteria, the evidence is that we were able to make our designs with better performance criteria than the previous works while keeping the same functionality.

IV. Our Proposed Design of Decoder 2 to 4, 3 to 8 and n to 2^n

In this paragraph we will present our circuits concerning the decoder 2 to 4, 3 to 8 and n to 2^n

Our work is based on the article [13] ,we try to modify it to improve certain performance criteria, starting with:

A. Decoder 2 to 4

We thought of exploiting its circuit 2 to 4 [13] by replacing the reversible gate SOM by that of the RD and to assign to the third and fourth input the value 0 Fig. 31 shows our design of decoder 2 to 4.

Concerning the performance criteria of our design we have CG=1,NGO=0 ,NCI)2,QC=8 et HC= 5 α + 2 β+2 δ

B. Decoder 3 to 8

After using the decoder circuit 3 to 8 of the [13], the reversible gate SOM has also been replaced by that of the RD, and the 2 reversible gates UM by 4 reversible gates RI.

Fig. 32 shows our design of decoder 3 to 8.

The performance criteria obtained are as follows: CG=5,NGO=1,NCI=6 ,QC=24 and HC=9α + 14 β+6 δ

C. Decoder n to 2^n

Our conception of decoding n to 2^n is done by adopting our decoder circuit 3 to 8 by adding to each reversible gate RI 2 reversible gates RI. Fig. 33 shows our design of the decoder n to 2^n.

The performance criteria obtained are as follows:

Concerning the performance criteria we have as follows:

1) lemma 1: CG = 2^n-3
Proof: we will demonstrate it recurrently for n = 2 we have CG = 2^2-3 =4-3= 1 that's correct because we have only one reversible gate which is RD.

Suppose that for n-1 we have CG = $2^n - 1$ -3 and prove for n we have CG = 2^n-3

for n on CG = 2^{n-1} -3+ 2^{n-1} because the n th column of the reversible gates RI we have in total $2^n - 1$ therefore CG = 2 *2^{n-1} -3 = 2^n-3 so it's correct then CG = 2^n-3

2) lemma 2: * NGO = n-2
Proof: we will demonstrate it recurrently for n = 2 we have NGO = 2-2 = 0 that's correct because the RD reversible gate has no garbage output.

Suppose that for n-1 we have NGO = n-1-2 =n-3 and prove for n we have NGO = n-2 for n on NGO = n-3+1 =n-2 because at the n th column of the RI reversible gates there is only one garbage output so it's correct then NGO = n-2

3) lemma 3: * NCI = 2^n-2
Proof: we will demonstrate it recurrently for n = 2 we have NCI = 2^2-2 = 2 that's correct because the RD reversible gate has 2 constants inputs.

Suppose that for n-1 we have NCI = $2^n - 1$-2 and prove for n we have NCI = 2^n-2 for n on CG = 2^{n-1}-2+2^{n-1} =2^n-2 because at the n th column of the RI reversible gates there we have 2^{n-1} so it's correct then NCI = 2^n-2

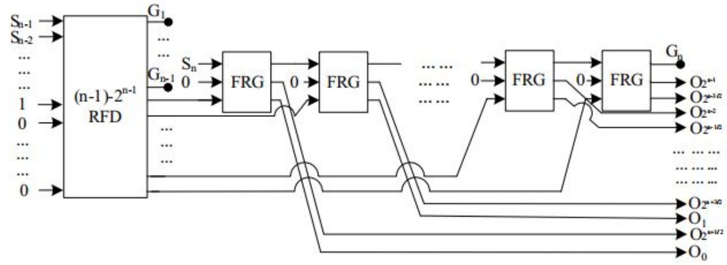

Fig. 30. Design Decoder n to 2^n used F2G and FRG.

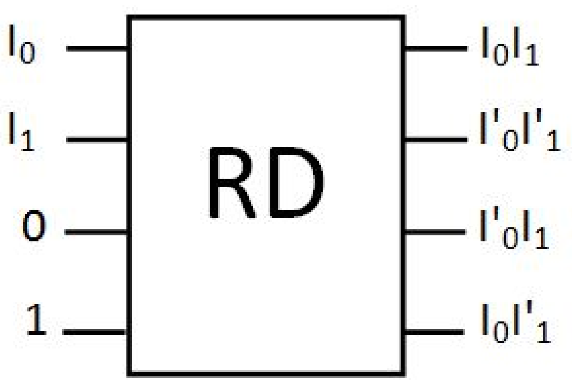

Fig. 31. Our Decoder Design 2 to 4.

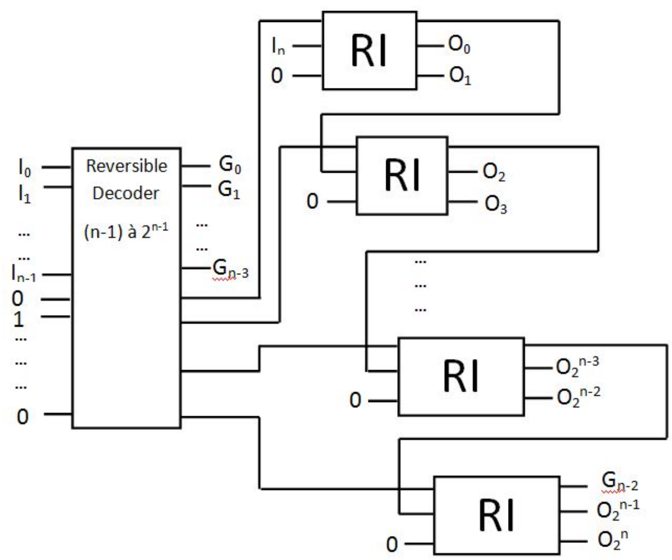

Fig. 33. Our Decoder Design n to 2^n.

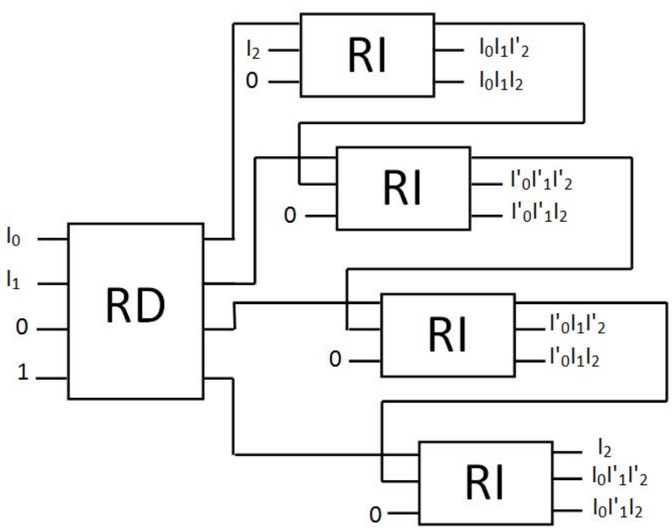

Fig. 32. Our Decoder Design 3 to 8.

4) lemma 4: * QC = 4 (2^n-2)

Proof: we will demonstrate it recurrently for n = 2 we have CG = 4 * (2^2 -2)= 4*(4-2)=8 that's right because the quantum cost of the reversible gate RD is 8.

Suppose that for n-1 we have QC = 4 ($2^n - 1$ -2) and prove for n we have QC = 4 (2^n-2)

for n on QC = 4 (2^{n-1} -2) + 4 * 2^{n-1} because at the n th column of the reversible gates RI we have in total 2^{n-1} reversible gates that we must multiply by 4 to have the quantum cost of the n th column so QC = 4 (2^{n-1} -2) + 4 *2^{n-1} = 4 (2^n-2) so it's correct then QC = 4 (2^n-2).

5) lemma 5: *HC = HC=5α+2β+2δ+2^{n-1}(1α+3β+1δ) =(2^{n-1}+5)α+(3*2^{n-1}+2)β+(2^{n-1}+2)δ

Proof: In our design of the decoder n to 2^n we have a reversible gate RD and 2 (n-1) reversible gates RI so we have

HC = HC (RD) + HC (2^{n-1} RI)

HC=5α+2β+2δ+2^{n-1}(1α+3β+1δ) =(2^{n-1}+5)α+(3*2^{n-1}+2)β+(2^{n-1}+2)δ

V. Result and Discussion

So in this paragraph we will compare our results obtained compared to recent studies of decoder 2 to 4, 3 to 8 and n to 2^n

A. Comparative Table of Decoder Performance Criteria 2 to 4, 3 to 8 and n to 2^n

.

After proving the results obtained from decoders 2 to 4, 3 to 8 and n to 2^n for our proposed designs and recent and exploited ones we can draw up the following tables showing the% improvement in performance criteria,starting with:

1) Comparative Table of Decoder Performance Criteria 2 to 4 : Table I shows the% improvement in performance criteria about decoder 2 to 4.

TABLE I. COMPARATIVE TABLE OF DECODER PERFORMANCE CRITERIA 2 TO 4

Decoder 2to4	CG	NGO	NCI	QC	HC
Our design	1	0	2	8	$5\alpha +2\beta+2\delta$
design1[13]	1	0	2	–	$5\alpha +4\beta+2\delta$
Design2 [13]	1	2	4	–	$6\alpha +4\beta+4\delta$
Design3 [9]	3	1	3	11	$5\alpha +8\beta+2\delta$
Design4 [9]	1	0	2	7	$7\alpha +9\beta+3\delta$
[14]	3	2	3	15	$6\alpha +24\beta+3\delta$
[10]	1	2	4	11	$6\alpha +4\beta+1\delta$
[11]	1	0	2	11	$5\alpha +7\beta+3\delta$
[15]	2	2	2	8	$2\alpha +6\beta+4\delta$
[12]	3	1	3	9	$5\alpha +8\beta+4\delta$
[16]	6	3	3	11	$7\alpha +2\beta+2\delta$
[17]	1	0	2	9	$7\alpha +1\beta$
[18]	3	2	4	12	$6\alpha +8\beta+2\delta$
%Imp Design1 [13]	–	–	–	–	50% of AND
%Imp Design2 [13]	–	100	50	–	16,67 CNOT , 50 (AND,NOT)
%Imp Design3 [9]	66,67	100	33,33	27,27	75AND
%Imp Design4 [9]	–	–	–	–	28,57CNOT 77,78AND 33,33NOT
%Imp [14]	66,67	100	33,33	46,66	16,67CNOT 91,66AND 33,33NOT
%Imp [10]	–	100	50	27,27	16,67 CNOT 50AND
%Imp [11]	–	–	–	27,27	71,42AND 33,33NOT
%Imp [15]	50	100	–	–	66,67AND 50NOT
%Imp [12]	66,67	100	33,33	11,11	75AND 50NOT
%Imp [16]	83,33	100	33,33	27,27	28,57CNOT
%Imp [17]	–	–	–	11,11	28,57CNOT
%Imp [18]	66,67	100	50	33,33	16,67CNOT 75AND

Based on the results obtained in the recent table, we were able to reduce in terms of:

-Number of gates: 66.67 % compared to design3 [9], design [14], design [12] and design [18], 50 % compared to design [15] and 83.33 % compared to design [16].

-Number of garbage outputs: 100 % compared to design2 [13], design3 [9], design [14], design [10], design [15], design [12], design [16] and design [18].

-Number of constant inputs: 50 % compared to design2 [13], design [11] and design [18], 33.33 % compared to design3 [9], design [14], design [12] and design [16].

-Quantum cost: 27.27 % compared to design3 [9], design [10], design [11], design [16], 46.66 % compared to design [14].

-Hardware Complexity: * number of CNOT gates: 16.67 % compared to design2 [13], [14] [10], [18], 28.75 % compared to design4 [9].

* Number of AND gates: 50 % compared to design1 [13], design2 [13], [10], 75 % compared to design3 [9], [12], design [18] 77.78 % compared to design4 [9], 91.66 % compared to design [14], 71.42 % compared to design [11] and 66.67 % compared to design [15]
* Number of NOT gates: 50 % compared to design2 [13], 33.33 % compared to design4 [9], [14].

From these results we draw up our Table 3.10 based on which we can present the graph containing the performance criteria in the form of bars Fig. 34.

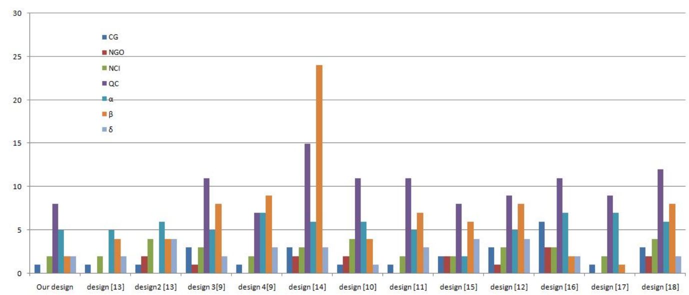

Fig. 34. Graph of Decoder Performance Criteria 2 to 4 of Recent Studies and our Design.

2) Comparative Table of Decoder Performance Criteria 3 to 8 : Table II shows the% improvement in performance criteria about decoder 3 to 8.

TABLE II. COMPARATIVE TABLE OF DECODER PERFORMANCE CRITERIA 3 TO 8

Decoder 3to8	CG	NGO	NCI	QC	HC
Our design	5	1	6	24	$9\alpha +14\beta+6\delta$
Design1[13]	3	3	8	–	$17\alpha +12\beta+10\delta$
Design2[13]	5	1	6	–	$13\alpha +12\beta+10\delta$
Design3[9]	7	2	7	31	$13\alpha +24\beta+6\delta$
Design4[9]	5	1	6	27	$15\alpha +25\beta+7\delta$
[14]	7	2	8	35	$14\alpha +28\beta+7\delta$
[10]	5	3	8	31	$14\alpha +20\beta+5\delta$
[11]	5	1	6	31	$13\alpha +23\beta+7\delta$
[15]	6	3	6	24	$6\alpha +18\beta+8\delta$
[12]	7	2	7	29	$13\alpha +24\beta+9\delta$
[19]	10	3	8	50	–
[16]	10	3	7	31	$15\alpha +18\beta+6\delta$
[18]	10	7	8	32	$14\alpha +24\beta+6\delta$
%Imp Design1[13]	–	66,67	25	–	47,05CNOT 40NOT
%Imp Design2[13]	–	–	–	–	30,76 CNOT 40NOT
%Imp Design3[9]	28,57	50	14,28	22,58	30,76CNOT 41,66AND
%Imp Design4[9]	–	–	–	11,11	40CNOT 44AND 14,28NOT
%Imp [14]	28,57	50	25	31,42	35,71CNOT 50AND 14,28NOT
%Imp [10]	–	66,67	25	22,58	35,71 CNOT 30AND
%Imp [11]	–	–	–	22,58	30,76CNOT 39,13AND 14,28NOT
%Imp [15]	16,67	66,67	–	–	22,22AND 25NOT
%Imp [12]	28,57	50	14,28	17,24	30,76 CNOT 41,66AND 33,33NOT
%Imp [19]	50	66,67	25	52	
%Imp [16]	50	66,67	14,28	22,58	40CNOT 22,22AND
%Imp [18]	50	85,71	25	25	35,71CNOT 41,66AND

Based on the results obtained in the recent table, we were able to reduce in terms of:

-Number of gates: 28.57 % with respect to design3 [9], design [14], design [12], 50 % with respect to design [19], design [16], design [18] and 16, 67 % compared to design [15].

-Number of garbage outputs: 66.67 % compared to design1 [13], design [10], design [14], design [15], design [19], design [16] 50 % compared to design3 [9] design [14] design [12] and 85.71 % compared to design [18].

Number of constant inputs: 25 % with respect to design1 [13], design [14] design [10], design [19] and design [18], 14.28 % with respect to design3 [9], design [12] and design [16].

-Quantum cost: 22.58 % compared to design3 [9], design [10], design [11], design [16], 11.11 % compared to design4 [9] 31.42 % by with respect to design [14] 17.24 % with respect to design [12] 52 % with respect to design [19] and 25 % with respect to design [18].

-Hardware Complexity: * number of CNOT gates: 47.05 % compared to design1 [13], 30.76 % compared to design2 [13] design3 [9] design [11], design [12], 35.71 % compared to design [14] design [10] design [18], 40 % compared to design [16].

* Number of AND gates: 41.66 % compared to design3 [9], design [12], design [18], 44 % compared to design4 [9] 50 % compared to design [14], 30 % with respect to design [10], 39.13 % with respect to design [11] 22.22 % with respect to design [15] and design [16]
* Number of gates NOT: 40 % compared to design1 [13], design2 [13] 14.28 % compared to design4 [9] 25 % compared to design [15], 33.33 % by in relation to design [12].

From these results we draw up our Table 3.11 based on which we can present the graph containing the performance criteria in the form of bars Fig. 35.

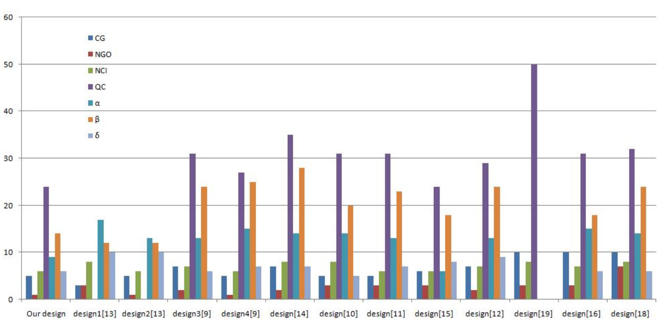

Fig. 35. Graph of Decoder Performance Criteria 3 to 8 of Recent Studies and Our Design.

*

3) Comparative Table of Decoder Performance Criteria n to 2^n : Table III shows the% improvement in performance criteria about decoder n to 2^n.

Then this table represents the performance criteria of each design of decoder n 2^n and the % improvement in terms of these of our design compared to recent decoders, all of these parameters of which are expressed as a function of n.

In the column of % improvement of HC we represent respectively our percentages of CNOT, AND and NOT which are separated by the symbol -.

After having presented the improvements obtained from our design of the decoder n at 2n in terms of performance criteria, we will assume that n tends to infinity in order to be able to give improvements of % and therefore to obtain the following Table IV.

Then when n tends to infinity we obtain the following improvements according to each performance criteria:

-Number of garbage outputs: 100% compared to design 1 [13].
-Number of constant inputs: 33% compared to design 1 [13].
-Quantum cost: 20% compared to design 3 [9] design 4 [9] design [14] design [15] design [12] design [19] and design [18] , 33% compared to design [19].
-Hardware complexity:
*Number of CNOT gates: 75% compared to design 2 [13], design 3 [9] design [14], design [15], design [12], design [18] 80% compared to design 1 [13] 50% compared to design 4 [9].
*Number of AND gates: 62,5% compared to design 3 [9], design [14], design [15], design [12],design [18] 25% compared to design 1 [13], design 2 [13],design 4 [9].
*Number of NOT gates: 75% compared to design 1 [13], design 2 [13], 50% compared to design 3 [9], design [14], design [15], design [12], design [18].

VI. Conclusion

Reversible logic occupies a important role in minimizing energy loss at the end of unused bits in the circuit compared to conventional logic computation.Our designs were able to minimize all performance criteria Number of gates CG, Number of constant inputs NCI, Quantum Cost QC, Hardware Complexity HC and especially the number of garbage outputs NGO in our design 2 to 4, 3 to 8, and n to 2^n, as a result a decrease in the energy dissipated at the end of unused bits because heat is directly related to fewer garbage outputs. While waiting for new reversible gates to exploit in the future, we can optimize decoder 2 to 4, 3 to 8, and n to 2^n respecting the performance, typically concerning minimizing heat energy.

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TABLE III. Comparative Table of the Performance Criteria of Recent Studies of the n to 2^n Decoder

nto2^n	CG	NGO	NCI	QC	HC
OD	2^n-3	n-2	2^n-2	4(2^n-2)	$(2^{n-1}+5)\alpha +(32^{n-1})+2\beta+(2^{n-1}+2)\delta$
Design1[13]	2^{n-1}-1	2^{n-1}+n-4	32^{n-1}-4	–	$(52^{n-1}-5)\alpha +(42^{n-1}-4)\beta+(42^{n-1}-6)\delta$
Design2 [13]	2^n-3	n-2	2^n-2	–	$(2^{n+1}-3\alpha + (2^{n+1}-4)\beta+(2^{n+1}-6)\delta$
Design3[9]	2^n-1	n-1	2^n-1	52^n-9	$(2^n + 1-3)\alpha+ (2^{n+2}-8)\beta+(2^n-2)\delta$
Design4[9]	2^n-3	n-2	2^n-2	52^n-13	$(2^n+7)\alpha+ (2^{n+1}+9)\beta+(2^{n-1}-3)\delta$
[14]	2^n-1	n	2^n	52^n-5	$(2^{n+1}-2)\alpha +(2^{n+2}-4)\beta+(2^n-1)\delta$
[10]	2^n-3	n	2^n	52^n-9	$(2^{n+1}-2)\alpha + (2^{n+2}-12)\beta+(2^n-3)\delta$
[12]	2^n-1	n-1	2^n-1	52^n-11	$(2^{n+1}-3)\alpha +(2^{n+2}-8)\beta+(2^n)\delta$
[19]	10	n	2^n	62^n	–
[18]	2^n-1	n	2^n	(52^n-8)	$(2^{n+1}-2)\alpha + (2^{n+2}-8)\beta+(2^n-2)\delta$
%Design1[13]		(2^{n-1}-2)/(2^{n-1}+n-4)	(2^{n-1}-2)/(32^{n-1}-4)		(42^{n-1}-10)/(52^{n-1}-5)— (2^{n-1}-6)/(42^{n-1}-4)—(32^{n-1}-8)/(42^{n-1}-6)
%Design2[13]	–	–	–	–	(32^{n-1}-8)/(2^{n+1}-3)—(2^{n-1}-6)/(2^{n+1}-4)—(32^{n-1}-8)/(2^{n+1}-6)
%Design3[9]	2/(2^n-1)	1/(n-1)	1/(2^n-1)	(2^n-1)/(52^n-9)	(32^{n-1}-8)/(2^{n+1}-3)— (52^{n-1}-10)/(2^{n+2}-8)—(2^{n-1})/(2^n-6)
%Design4[9]	–	–	–	(2^n-5)/(52^n-13)	(2^{n-1}+2)/(2^n+7)—(2^{n-1}-11)/(2^{n+1}-9)— (1/(2^{n-1}-3)
%[14]	2/(2^n-1)	2/n	1/(2^{n-1})	(2^n+3)/(52^n-5)	(32^{n-1}-7)/(2^{n+1}-2)— (52^{n-1}-6)/(2^{n+2}-4)— (2^{n-1}-3)/(2^n —-1)
%[10]		2/n	1/2^{n-1}	(2^n-1)/(52^n-9)	(32^{n-1}-7)/(2^{n+1}-2) — (52^{n-1}-14)/(2^{n+2}-12)— (2^{n-1}-5)/(2^n-3)
%[12]	2/(2^n-1)	1/(n-1)	1/(2^n-1)	(2^n-3)/(52^n-11)	(32^{n-1}-8)/(2^{n+1}-3)—(52^{n-1}-10)/(2^{n+2}-8)—(2^{n-1}-2)/(2^n)
%[19]		2/n	1/(2^{n-1})	(2^{n+1}+8)/(62^n)	
%[18]	2/(2^n-1)	2/n	1/(2^{n-1})	(2^n)/(52^n-8)	(32^{n-1}-7)/(2^{n+1}-2)—(52^{n-1}-10)/(2^{n+2}-8)—(2^{n-1}-4)/(2^n-2)

TABLE IV. comparative Table of the Performance Criteria of Recent Studies of the n to 2^n Decoder when n Tends to Infinity

Decoder n à 2^n	CG	NGO	NCI	QC	HC
% Imp Design1[13]		100	33		80 CNOT, 25 AND , 75NOT
%Imp Design2[13]					75 CNOT, 25 AND , 75NOT
% Imp Design3[9]	0	0	0	20	75 CNOT, 62,5 AND , 50NOT
% Imp Design4[9]				20	50 CNOT, 25 AND
% Imp [14]	0	0	0	20	75 CNOT, 62,5 AND , 50NOT
% Imp [15]		0	0	20	75 CNOT, 62,5 AND , 50NOT
% Imp [12]	0	0	0	20	75 CNOT, 62,5 AND , 50NOT
% Imp [19]		0	0	33	
%Imp [18]	0	0	0	20	75 CNOT, 62,5 AND , 50NOT

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Grammatical Error Correction with Denoising Autoencoder

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***Abstract*—A denoising autoencoder sequence-to-sequence model based on transformer architecture proved to be useful for underlying tasks such as summarization, machine translation, or question answering. This paper investigates the possibilities of using this model type for grammatical error correction and introduces a novel method of remark-based model checkpoint output combining. This approach was evaluated by the BEA 2019 shared task. It was able to achieve state-of-the-art F-score results on the test set 73.90 and development set 56.58. This was done without any GEC-specific pre-training, but only by fine-tuning the autoencoder model and combining checkpoint outputs. This proves that an efficient model solving GEC might be trained in a matter of hours using a single GPU.**

Keywords*—*Denoising autoencoder transformer; sequence-to-sequence; grammatical error correction; model ensembling; error remarks filtering; fine-tuning

I. Introduction

Grammatical Error Correction (GEC) is a language processing task whose target is to detect and correct any mistake that could be found in input data, without changing the meaning intended by an author.

According to the British Council, English is spoken at a useful level by more than a quarter of the world's population [1]. Most of English users are not native speakers and posses different levels of proficiency. Therefore, all tools aimed for improving language correctness and assisting learning process would be of great importance.

There are two main approaches in solving Grammatical Error Correction task by neural models. First is to treat GEC as a form of Neural Machine Translation, where erroneous source texts are "translated" into correct ones (for example, [2] and [3]). The other way is to treat GEC as a sequence classification task, where model provides probability distribution over available corrections for every token ([4] and [5]).

From many approaches to create a GEC-solving system, so far the best results (BEA 2019 shared task [6] test set) have been reported by GECToR [4]. They propose a sequence tagging model that classifies input text tokens in a few iterations to identify the errors. They use pre-trained transformer-based encoders with dense layers on top that select one of possible token-level transformations. This architecture aids fast inference, since there is no need to sequentially decode output tokens as in NMT-like solutions. The model training was done in three phases, using a large amount of parallel synthetic data at first and then tuning on smaller higher quality sets (NUCLE, LANG8 [7], FCE, WI+LOCNESS).

In [2] was introduced the most recent sequence-to-sequence approach that uses a transformer-based encoder model as a base for sequence-to-sequence system. The base encoder model is pre-trained BERT ([8]), which is then fine-tuned on GEC data. This fine-tuning is perform on two tasks: MLM (Masked Language Model objective from [8]) and GED (Grammatical Error Detection). The encoder model adjusted this way is used to generate additional features in a sequence-to-sequence target model.

Problem of an inadequate amount of supervised training data was addressed in [9] and approached by using confusion sets to generate pseudo-data and pre-trains a sequence-to-sequence transformer. In [3] pseudo-data generation was performed via back-translation.

The main challenge of GEC is a very limited amount of annotated training data. It is relatively easy to acquire parallel texts for Machine Translation, while there are plenty of sources that provide texts in different languages. Corrected text, on the other hand, which are used for GEC, need to be proofread by human annotators. Preferably, every text should be reviewed multiple times, as in a test set for [6] and in [10].

Another aspect of this GEC task that might need closer attention is making better use of quickly improving language models. Both [2] and [4] include knowledge from models like BERT or XLNet in their approaches, but they also require quite complex pre-training phases with generated pseudo-data. The main advantage of relying more on a general-purpose model is that the target GEC system will get better together with constantly improving language models.

This paper investigates the possibilities of applying pre-trained sequence-to-sequence models for grammatical error correction and proves that fine-tuning is sufficient for achieving an efficient error correction model. This approach enables developing such models relatively quickly, with limited computational resources and limited data. Furthermore, after applying remark combination, it is possible to improve state-of-the-art results for GEC.

II. Model

In this section we describe our design decisions regarding model architecture, training and processing model output.

A. Architecture

In our approach we treat GEC as a sequence-to-sequence text transformation task, similar to machine translation. We choose the Transformer architecture ([11]) for our model because of plenty of successful applications of this model type in NLP problems (for example, machine translation [12], summarization [13] or question answering [14]). The most imporant transformer-based sequence-to-sequence models are GPT-2 ([15], T5 ([16]) and BART ([17]). Therefore, we use the pre-trained transfomer-based sequence-to-sequence model. Unlike encoder-models like BERT, XLNet, etc. they were pre-trained on full text-to-text tasks. We choose BART as our base model because of text denoising as its pre-training objective. This method makes it a natural candidate to solve GEC which may be seen as reconstructing correct text from some erroneous input. Our best results were achieved through BART large, which contained 12 encoder and 12 decoder layers and embedding dimension size equal to 1024.

B. Training

In contrast to other text generation tasks, in GEC difference between input and output text is relatively small. That impacts training and inference of the model. During training we try to set up configuration that would lead model to copy an input to the output with corrected language as the only adjustment. We noticed that both the amount of training data and training time need to be small and accurately selected to meet this goal. In Section IV we will describe the impact of data set source and size.

C. Inference

As for inference, an important distinction from other NLP tasks is the type of a decoding method. For example, in Machine Translation a common approach is to use Beam Search heuristic or such methods as Sampling, Sampling with Temperature ([18]) to aid diverse and human-like, natural output. However, in our model, applying Beam Search or Sampling led to very noisy output, and the best results required greedy selection of elements in the generated sequence (so the Beam parameter was set to 1).

D. Ensembling Method

The final output of the GEC task might be considered a set of text remarks that transforms the original text into the target one. It might be beneficial from the educational point of view, but also might be used to achieve performance improvement by combining remarks from multiple model instances. ERRANT [19] grading and annotation tool enables one to extract atomic remarks from parallel texts. Fig. 1 show examples of annotated sentences. The lines starting with S contain original sentences, following the lines starting with A which contain remarks. Every remark describes the annotation span, type and value. For example, in the sentence from Listing 1: *I think that the public transport will always be in the future* the first remark suggests removing the definite article, by defining the span from the 3rd to 4th token and empty replacement text. The second remark suggests replacing the infinitive *be* with *exist*.

We propose a simple and effective algorithm of combining remarks. Every model returns remarks for input text. Same remark may be produced by multiple models. Let us define output of a model i as:

$$M_i = \{r_1, .., r_N\} \tag{1}$$

where r is a single text remark. Then multi-set of model ensemble output M is defined as a tuple:

$$M = \left(\bigcup_i M_i, m\right) \tag{2}$$

where m is a function that gives every remark its number of occurrences:

$$m : \bigcup_i M_i \to \mathbb{N} \tag{3}$$

In practice, for simple texts, all sets of remarks are exactly the same. For more ambiguous texts, different model checkpoint outputs will differ. To combine different remark sets, we define the parameter R, which stands for *required remark frequency*, so the ensemble output M_e will be:

$$M_e = \{r : r \in M \wedge m(r) \geq R\} \tag{4}$$

Only the remark present in at least R model outputs will be chosen to the combined output. For example, if $R = 1$, we take all remarks from all models, and if $R = N$, where N equals a number of model checkpoints, only the remarks present in all model outputs are used in the target output. Increasing R forces only highly probable remarks to be selected for the target set; decreasing R results in selecting more remarks for the target set (see Fig. 2 that displays impact of R on Precision and Recall).

TABLE I. TRAINING DATA SETS. SENTENCE COUNT BEFORE AND AFTER FILTERING SENTENCES WITHOUT ERRORS

Name	Sentences	After filtering
WI+Locness	34308	34230
FCE	28350	28330
NUCLE	57113	21314
LANG-8	1041409	574180

III. DATA

Four publicly available data sets were used for training experiments (listed in Table I), all of them having been described for the BEA 2019 Workshop shared tasks [6].

During the pre-processing, all sentences whose byte-pair representation was longer than 400 were removed from the training set (it was no more than 0.5
% of all data), which allow for using bigger batches during the training. This, in turn, sped up model convergence. Furthermore, we tried the approach introduced in [2] and removed sentence pairs without any corrections. We achieved the best results after all the correct sentence pairs were removed from the NUCLE and LANG-8 datasets.

```
S Maybe I 'll change my mind , maybe not .
A -1 -1|||noop|||-NONE-|||REQUIRED|||-NONE-|||0

S I think that the public transport will always be in the future .
A 3 4|||U:DET|||||REQUIRED|||-NONE-|||0
A 8 9|||R:VERB|||exist|||REQUIRED|||-NONE-|||0

S The rich people will buy a car but the poor people always need to use a bus or taxi .
A 0 2|||U:DET|||Rich|||REQUIRED|||-NONE-|||0
A 7 7|||M:PUNCT|||,|||REQUIRED|||-NONE-|||0
A 8 9|||U:DET|||||REQUIRED|||-NONE-|||0
```

Fig. 1. Examples of Sentences Annotated by ERRANT. Every Annotation Line (Starting with `A`) Describes Source Text Adjustment (Starting with `S`). Every Annotation Defines the Span, Remark Type and Replacement Text.

Multiple evaluation sets is an important criterion to prevent domain overfitting. The model is evaluated on Write and Improve development and test datasets introduced in [6], the CONLL2014 test set introduced in [10] and the FCE test dataset adjusted for the BEA workshop.

Evaluation on WI+Locness was performed by ERRANT [19]. The FCE and CONLL dataset results were measured by the M2 scorer [20]. However, except Table VI, all the results were reported by the ERRANT score. The M2 scorer was used only to allow for comparison with other reported results.

ERRANT and M2 evaluation method is based on text edits comparison. For every input sentence, measured system outputs some hypothesis. This hypothesis might be considered as a set of text edits E.

$$E = \{e_1, .., e_n\} \tag{5}$$

Every sentence has some gold standard edits G.

$$G = \{g_1, .., g_n\} \tag{6}$$

[20] defines precision and recall of system hypothesis as:

$$P = \frac{\sum_{i=1}^{n} |e_i \bigcap g_i|}{\sum_{i=1}^{n} |e_i|} \tag{7}$$

$$R = \frac{\sum_{i=1}^{n} |e_i \bigcap g_i|}{\sum_{i=1}^{n} |g_i|} \tag{8}$$

ERRANT and M2 display system edits and the gold standard in a format defined in Section II-D. ERRANT additionally generates results indicating specific error categories (such as `M:PUNCT`, which stands for *missing punctuation*).

IV. Experiments

During our experiments we measured the impact of different factors on model performance on GEC task. In Section II we emphasise the specifics of GEC. We noticed that our model setup was very sensitive for the quality and type of training data. On the other hand, a small amount of training data required precise selection of training time and learning rate to prevent overfitting. We reduced a dropout to 0.05 - higher values slowed down the model convergence and did not give any long-running benefits.

TABLE II. Training Configurations

Model size	base	large
Number of epochs	2	2
Max sentences in batch	256	16
Max tokens	512	512
Max updates	8216	8772
Warm-up	411	414
Learning rate	7e-05	3e-05
Dropout	0.05	0.05

The model was trained using the Fairseq toolkit [21], adopting the general configuration designed for translation tasks. This setting requires providing dictionaries, which in our case were the same for both the source and target language. The baseline model was BART in two versions: base (140M parameters) and large (400M parameters). BART requires text pre-processed by the byte-pair encoder, introduced in [15].

All experiments were performed on single GPU (Geforce RTX 2080 11GB), on Python version 3.7.6.

A. Configuration

An optimizer used for training was Adam [22] with label-smooth cross-entropy loss function [23]; the learning rate was set according to a polynomial schedule. All the training and learning rate schedule parameters, except those listed in Table II, were left unchanged from their default values. The polynomial schedule in its default configuration (a polynomial degree equals 1) basically increases the learning rate from 0 to the max value during warm-up phase and then linearly decreases. Token and sentence limits were set to facilitate a single batch fit into the available GPU memory.

B. Data Set Impact

In our approach, the base model is already trained on reconstructing noisy text. During the fine-tuning phase, we show pairs of correct/incorrect text, which alters model behavior to precisely fix a specific set of text modifications. We investigated the impact of including different data sets into the training set. Table III shows detailed results achieved on three development sets, while adding data to the training set. It proved to be important that a training data includes high-quality corrected texts (WI, FCE), and adding texts from other sources may degrade model performance.

Training only on the WI dataset yields average results of 53.65 for WI and 54.38. These results are almost as good as achieved by bigger training sets, but on FCE it gets only 48.49, which is significantly worse than further results. Adding the FCE training set improves score on the FCE test set to 53.22, without degrading results on other test sets. After adding $NUCLE$, average results on FCE increases slightly to 53.73 and on CONLL-14, to 55.75. However, the models trained only on WI and FCE, without $NUCLE$, achieve better result when multiple model output is combined. Data from the LANG-8 dataset caused quite a significant drop on all the test sets, which might be caused by difference in annotation quality between the training and test data. The LANG-8 annotations were created by native speakers - collaborative users of the LANG-8 learning service. The WI test set was created from selected *Write and Improve* service submissions, mixed with parts of the *LOCNESS* essay corpus and annotated 5 times by *Write and Improve* annotators.

C. Model Size Impact

For comparison, Table IV shows results for a smaller version of pre-trained BART containing 140M parameters. Both model types were trained from 10 different random initialization points. Results reported in the table are: the best checkpoint result, an average of all 10 checkpoints, an ensemble containing 3 models (an average of 10 random combinations of size 3) and an ensemble containing all 10 models. A detailed description of the ensembling method is provided in Section IV-D.

The smaller model achieves an average of 41.96 F-score, which, comparing to the LARGE version score of 53.36, is significantly worse, but its inference time is 2 times better, which might be an important quality when considering the production use.

D. Combining Output

Table V shows a change of $F_{0.5}$ on BEA-Dev dataset while changing values of R and N (parameters of the output combination algorithm, see Section II), and Fig. 2 showcases a trade-off between precision and recall for an ensemble of 10 checkpoints and a changing value of R.

The different model checkpoints are trained using the same train sets and configuration, but are initialized with different random values. Adding models to an ensemble allows for better overall correction-quality but requires longer inference time.

Thanks to the method described in Section II, the overall reported performance for BEA19 can increase by almost 4%, where a single model achieves 69.80, and after ensambling, it reaches 73.90.

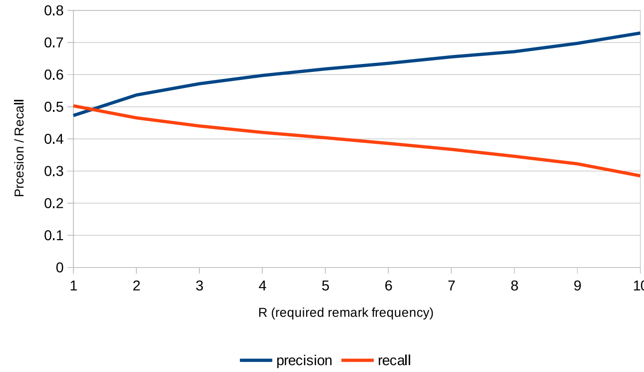

Fig. 2. Impact of Changing Remark Frequency R (see Section II-D) for Ensemble of 10 Models. Measurements were Performed on BEA-dev. For Detailed Results on Different Ensembles see Table V.

E. Results Summary

Single models were selected by comparing results from development sets, so the value reported on the BEA19 test comes from the checkpoint that achieved the best result on the BEA19 development set. In the case of CONLL14, where there is no development set available, the reported value is an average of 10 randomly initialized checkpoints. Table VI comprises results reported in current research papers and those achieved by our model. We report the best score on the BEA19 test and development sets. The scores on CONLL2014 and FCE are not far from the best reported results. These results, achieved by relatively low-resource fine-tuning, suggest that the GEC models might greatly benefit from a pre-trained model. A sequence-to-sequence denoising pre-training objective uses similar text transformations, as commonly required in GEC. [17] uses token masking, token deletion, token infilling, sentence permutation and document rotation. After fine-tuning, the model identifies a subset of these transformations specific to GEC. Remark-based ensambling proved to be a reasonable method to increase the correction precision, which improves the overall score, but it is also important for further model applications, where false positive remarks might be very misleading, especially in educational systems.

V. Conclusion and Future Work

A fine-tuned sequence-to-sequence transformer model is very effective in solving the GEC task. It was able to achieve state-of-the-art results on the BEA19 test set 73.90 and development set 56.58. It proves that an efficient model solving GEC might be trained in a matter of hours using a single GPU. Only a limited amount of human-annotated data was required.

What is also beneficial in our approach is that it facilitates leveraging future progress in general-purpose language models. Single language models followed by multi-lingual systems will enable solving GEC for languages other than English. Constantly expanding transformer-based models extend the limits of text comprehension and may improve GEC performance without costly data annotation and only with low-resource and fast fine-tuning.

TABLE III. RESULTS ACHIEVED FOR TRAINING SETS CONTAINING DATA FROM DIFFERENT SOURCES. COLUMN MAX DISPLAYS BEST CHECKPOINT, AVG AVERAGE RESULT, ENS 10 RESULT AFTER COMBINING CHECKPOINTS FROM ALL REMARKS

Train data	Sentence count	**BEA-dev (ERRANT)**		
		max	avg	ens 10
W&I	34K	53.65	53.34	56.74
W&I, FCE	63K	54.07	53.36	56.58
W&I, FCE, NUCLE	84K	53.29	52.73	55.42
W&I, FCE, NUCLE, LANG8	658K	48.87	35.79	41.03
Train data	Sentence count	**FCE-test (ERRANT)**		
		max	avg	ens 10
W&I	34K	49.35	48.49	51.61
W&I, FCE	63K	53.72	53.22	57.48
W&I, FCE, NUCLE	84K	54.5	53.73	57.94
W&I, FCE, NUCLE, LANG8	658K	52.58	52.18	56.46
Train data	Sentence count	**CoNLL-14 (ERRANT)**		
		max	avg	ens 10
W&I	34K	54.95	54.38	58.82
W&I, FCE	63K	55.48	54.68	58.81
W&I, FCE, NUCLE	84K	56.28	55.75	57.94
W&I, FCE, NUCLE, LANG8	658K	55.58	54.63	57.04

TABLE IV. RESULTS FOR DIFFERENT MODEL SIZES

Model size	parameters	**BEA-dev (ERRANT)**			
		max	avg	ens 3	ens 10
BASE	140M	44.34	41.96	43.32	45.66
LARGE	400M	54.07	53.36	56.19	56.58
Model size	parameters	**FCE-test (ERRANT)**			
		max	avg	ens 3	ens 10
BASE	140M	45.29	42.20	45.97	47.08
LARGE	400M	53.72	53.22	57.04	57.48
Model size	parameters	**CoNLL-14 (ERRANT)**			
		max	avg	ens 3	ens 10
BASE	140M	48.23	46.30	48.36	50.13
LARGE	400M	55.48	54.68	58.70	58.81

TABLE V. BEA-DEV RESULTS FOR ENSEMBLES CONTAINING DIFFERENT MODEL COUNT (PARAMETER N ON HORIZONTAL AXIS) AND CHANGING REMARKS FREQUENCY PARAMETER R (VERTICAL AXIS, SEE SECTION II-D)

R/N	2	3	4	5	6	7	8	9	10
1	52.83	51.72	51.03	50.12	49.59	48.99	48.60	48.22	47.85
2	55.87	55.46	54.76	54.18	53.74	53.21	52.79	52.42	52.07
3		56.19	56.09	55.82	55.37	55.04	54.66	54.28	53.95
4			56.15	56.47	56.25	56.02	55.67	55.39	55.10
5				56.10	56.49	56.44	56.30	56.05	55.85
6					56.04	56.62	56.57	56.50	56.27
7						55.94	56.60	56.56	56.66
8							55.86	56.57	56.52
9								55.73	**56.58**
10									55.62

TABLE VI. RESULTS SUMMARY (MEASURED BY ERRANT EXCEPT TWO COLUMNS FOR CONLL14 AND FCE-TEST LABELED ACCORDINGLY AS MEASURED BY M^2 SCORER)

	Results				
	BEA-test	**BEA-dev**	**CoNLL14** (M^2)	**CoNLL14**	**FCE-Test** (M^2)
Single model result					
GECToR [4]	72.40	55.50	65.30	-	-
Transformer + Pseudo data[3]	64.20	45.90	61.30	56.00	-
BERT-fuse[2]	-	-	-	-	**61.20**
Model ensembles					
GECToR [4]	73.63	-	**66.50**	-	-
Combined systems [24]	73.18	-	-	-	-
Transformer + Pseudo data[3]	70.20	-	65.00	**60.90**	-
BERT-fuse[2]	69.80	-	65.20	-	59.40
Transformer + Pseudo data based on confusion sets[9]	69.47	53.00	64.16	-	55.81
Sequential transfer learning [25]	69.06	52.79	-	-	-
Ours – single model	69.80	54.36	61.92	55.27	59.11
Ours – 3 models	73.13	56.19	62.48	58.70	59.32
Ours – 10 models	**73.90**	**56.58**	62.48	58.81	59.54

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A Unique Glottal Flow Parameters based Features for Anti-spoofing Countermeasures in Automatic Speaker Verification

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Abstract—**The domain of Automatic Speaker Verification (ASV) is blooming with growing developments in feature engineering and artificial intelligence. Inspite of this, the system is liable to spoofing attacks in the form of synthetic or replayed speech. The difficulty in detecting synthetic speech is due to recent advancements in the Voice conversion and Text-to-speech systems which produce natural, indistinguishable speech. To prevent such attacks, there is a need to develop robust spoof detection systems. In order to achieve this goal, we are proposing estimation of Glottal Flow Parameters (GFP) from speech of genuine speech and synthetic spoof samples. The GFP are further parameterized using time, frequency and Liljencrants–Fant (LF) models. Along with GFP features, the Linear Prediction Cepstrum Co-efficient (LFCC) and statistical parameters are computed. The GFP features are investigated to prove their usefulness in detecting spoofed and genuine speech. The ASV spoof 2019 corpus is used to test the framework and evaluated against the baseline models. The proposed spoof detection framework produces an Equal Error Rate (EER) of 2.39% and tandem Detection Cost Function (t-DCF) of 0.0562 which is found to be better than the state-of-the art technique.**

Keywords—Spoof detection; synthetic speech; glottal excitation; speaker verification; voice conversion; text-to-speech

I. Introduction

The speaker verification system acknowledges the true identity of a known speaker while dismissing the unknown speaker's voice [1]. These systems are bound to be exposed to the infiltrators through spoofing attacks. The intrusion in the form of synthetically generated speech results into spoofing attack on the ASV system. Such an environment is termed as Logical Access (LA) scenario while the one with replay speech is a Physical Access (PA) scenario [2]. These attacks are a result of continuous efforts by researchers in field of Voice Conversion (VC) and Text-to-Speech (TTS) [3]; since their aim is to generate clean, human like speech - with little to no variation in the synthetic speech. Hence, tackling these attacks through means of efficient features and machine learning algorithms are a desideratum. The studies in anti-spoofing or countermeasures have increased tremendously with increasing attacks on main-frame systems such as phone-banking theft, unauthentic access to workplaces or even smart phone devices where speech is used as the identity [3], [4]. So, as authentication is no more limited to finger prints and retina scans, the speech based spoofing attacks are growing and catching attention of many researchers for developing robust spoofing detection schemes. Moreover, the countermeasures developed so far are less than a decade old and still have a scope of improvement in terms of reducing the False Acceptance ratios. Most of the research is based on specific type of attack [5], [6] while few others consider all the types of attack making them universal detectors [7], [8].

II. Related Work

The anti-spoofing measures are solely dependent on two prime techniques: feature representation and spoofed speech classification. The studies on features are significant and need to be based on the nature of input speech which is either genuine or spoofed. Thus, the task is restricted to differentiate between spoofed and genuine speech through appropriate use of features for extracting relevant information from the test speech. The spectral features employed for spoofing detection are Mel-Frequency Cepstral Co-efficient (MFCC) [9], [10], Magnitude and Phase based features [11] such as Log Magnitude Spectrum, Residual Log Magnitude Spectrum, Group Delay (GD), Modified GD (MGD), Instantaneous Frequency (IF), Baseband Phase Difference and Pitch Synchronous Phase (PSP). Additionally, the known fact that the MFCCs represent the human auditory system as it utilizes perceptually similar filter bank analysis, is found to be performing not so well in the anti-spoofing environment [11]. To counter that, the Inverse MFCC (IMFCC) is proposed for spoof detection because it comprises of feature contents which are absent in MFCC [12]. Furthermore, the CFCCIF, CQCC based features were also proposed; out of which CQCCs are considered to outperform in the ASV Spoof 2017 challenge [13], [14].

The features extracted are trained using machine learning algorithms ranging from generative models like i-vectors [15], Gaussian Mixture Models (GMM) [10], [16], Universal Background Models (UBM)[17], [18], [19] and Joint Factor Analysis [15] to discriminative models like Support Vector Machines (SVM) [20], Deep Neural Networks [21], [22], [23] and its variants like Recurrent Neural Networks (RNN) [24], [25], Deep Residual Neural Networks [13] and Convolutional Neural Network (CNN) [26], [27]. The GMM are considered to be efficient in capturing the generality and non-linearities in data [2]. Therefore, we are using the state-of-the art GMM for learning the pattern to differentiate genuine and spoofed speech.

The speech signal generated by lungs act as a source of air that stipulates excitation from glottis resulting into resonating frequencies traveling through the vocal tract out of the mouth. Hence, the lip radiation is also considered as the part of the production mechanism but is stable. Thus analytically, the contents available from speech may be in the form of meaning of the utterance and individual speaker's identity. For designing the counter-measure to detect an attack, the extraction of speaker related information and artefacts inserted due to synthetic speech is a crucial step. Both identity of speaker and meaning of sample can be interpreted at different areas of the production mechanism like shape of Vocal Tract (VT), nature of Glottal Excitation (GE) or flow and prosody parameters [28]. The work in this research is based on analysing the source of the speech production model, i.e. glottal source estimation technique. The research in [20] used IAIF estimation for glottal flow estimation but focused more on the classifiers (SVM and ELM). Along with this, we consider the VT information which captures the speaker's individuality in the form of LFCC [29] with statistical parameters. Also, the few studies have shown glottal excitation to be independent of VT [30] while some have shown inter-dependency between them [31], [32], [33]. Hence, we found it necessary to explore glottal excitation components of genuine and spoof speech. Furthermore, the scope of the research is also confined to LA attacks as synthetic speech production is becoming more accessible and capturing naturality. This is due to the fact that open source tools and datasets are available for researchers to explore leading to more versatile synthetic speech generators [5], [23], [34], [35].

Thus, the research approach is divided in a three-fold process and is listed as follows:

1) Exploring the Glottal Flow Parameters (GFP) using Quasi-Closed Phase estimation and LF modelling to capture the inaudible artefacts present in the synthetic speech through careful representation of source excitation process.
2) Investigating the performance of these GFP features using objective metrics in the GMM framework.
3) Conducting comparative analysis of the proposed features with the Baseline LFCC features [2].

The article is organized as follows: Section III describes the Glottal excitation estimation based Feature Extraction while Section IV elaborates the Proposed Anti-spoofing based speaker verification system. The Section V presents the experimental results while overall discussion and conclusion are summarized in Sections VI and VII, respectively.

III. Glottal Excitation Estimation Based Feature Extraction

The estimation of source of the speech by filtering out the effects of lip radiation and vocal tract is termed as Glottal inverse filtering (GIF). The first research on glottal source estimation began in 1950s by Miller [36]. Since then, improvements were seen in representing glottal source, but it has been difficult to compute due to lack of ground truth like no EGG information available. Furthermore, studies directed towards utilizing synthetic speech to work on in order to avoid the need for ground truth [37]. In the spoof detection task, this research is analyzing natural as well as synthetic speech (which is indeed spoofed speech). The GIF analysis was initially based on closed phase, iterative and adaptive approaches [38]. The Closed phase estimation is based on the covariance criteria for Linear Prediction (LP) analysis as some samples which are present in closed phase. Another approach that requires prior knowledge of shapes of both vocal tract as well as glottal excitation is the Iterative Adaptive Inverse Filtering (IAIF) [31]. The mixed phased approaches like Complex Cepstrum analysis [39] and zeros of Z-transform (ZZT) [40] are contrasting to the earlier estimation techniques as they consider segregation of glottal and vocal tract information through transformation in another domain (such as frequency or z-domain). Furthermore, the Mean-Square Phase (MSP) is used to approximate the Liljencrants-Fant (LF) model [41]. Most of approaches mentioned so far perform well for low pitched male voices and deteriorate for higher fundamental frequencies (f0) [38]. This research is based on Quasi-Closed Phase (QCP) glottal estimation that uses Weighted Linear Prediction (WLP) in place of covariance criteria as shown in Fig. 1. It is found that this kind of estimation is more robust in the closed phase parts of the speech samples [38]. Also, so far studies have been conducted on VT contents of the speech whereas the glottal excitation is equally important as it bears the source of speech production system.

The speech produced because of convolution in time domain, s_m turns out to be product of individual frequency responses of GE source, $G(z)$ and VT filter $T(z)$. Thus, speech signal $S(z)$ in z-domain is given in Equation 1

$$S(z) = G(z).T(z) \tag{1}$$

So, using the conventional LP approach for portraying the WLP model for m^{th} speech utterance as shown in Equation 2

$$s_m = \sum_{j=1}^{L} s_{m-j} b_j + e_m \tag{2}$$

Where, e_m is excitation signal with j^{th} b_j prediction coefficient of order L. The significant difference between WLP and LP analysis is that the WLP yields the product of weight function W_m with square of the excitation signal given in the form of Total energy residual E (in Equation 3):

$$E = \sum_{m=m_1}^{m_2} (s_m - \sum_{j=1}^{L} s_{m-j} b_j)^2 W_m \tag{3}$$

For auto-correlation criteria, the limits $m_1 = 1$ and $m_2 = M + L$; M is the length of frame. The weight function, W_m is given in Equation 4 using Attenuated Main Excitation (AME) function.

$$W_m = \sum_{i=0}^{N-1} s_{m-1-j}^2 \tag{4}$$

The Glottal Flow waveform obtained from the raw speech samples of genuine speech (Fig. 2a), TTS synthetic speech (Fig. 2b) and the VC speech (Fig. 2c) signify the difference in time, frequency and phase contents of genuine and synthetic speech samples.

The QCP parameters include the time, amplitude and frequency domain traits contributing to 31 Glottal flow descriptors. The time domain parameters considered in this research

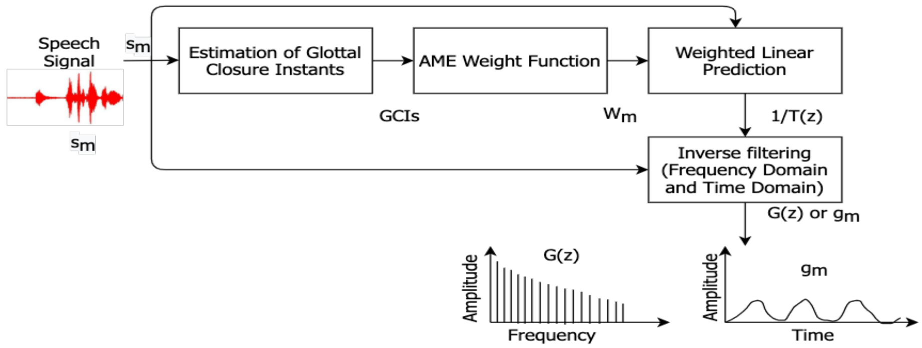
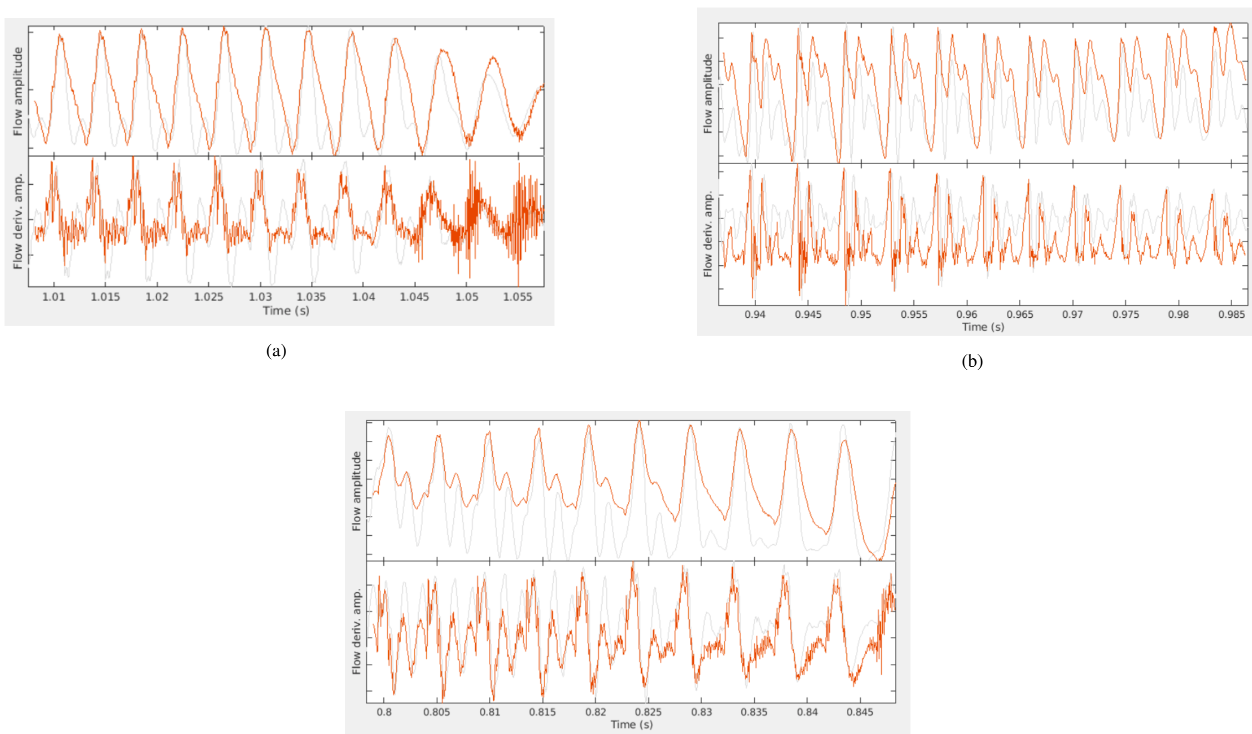


Fig. 1. Block Diagram of GFP based Feature Extraction using QCP Estimation.



(a)

(b)

(c)

Fig. 2. Glottal Flow Derivative and Amplitude Waveform for (a) Genuine (b) TTS (c) VC Speech Samples.

are based on open quotient (OQ), speed quotient (SQ), and closing quotient (ClQ) while the amplitude parameters are based on Amplitude Quotient (AQ). Lastly, the frequency domain parameters such as Parabolic spectrum parameter (Psp), difference value between amplitude of first and second harmonic (H1-H2) and Harmonic Richness Factor (HRF) which are adapted from [37] are also computed as a part of GFP features.

IV. Proposed Anti-spoofing Speaker Verification Framework

A spoof detection or anti-spoofing algorithm must be designed by carefully choosing the right features which represent the spoof and genuine speech in order to make the differentiation task easier. Hence, the choice of appropriate classifier too, is crucial. To summarize the spoof detection system, there two primary phases, namely the training phase and the testing phase as shown in Fig. 3. The training phase involves extracting the GFP, LFCC and statistical features after pre-processing of the raw speech data. These features are fed to the GMM classifier using associated labels. The individual models for genuine and spoofed samples are used in the testing phase to categorize the unknown test sample. The details steps: parameterization, model training and decision making algorithm are described in further sub-sections.

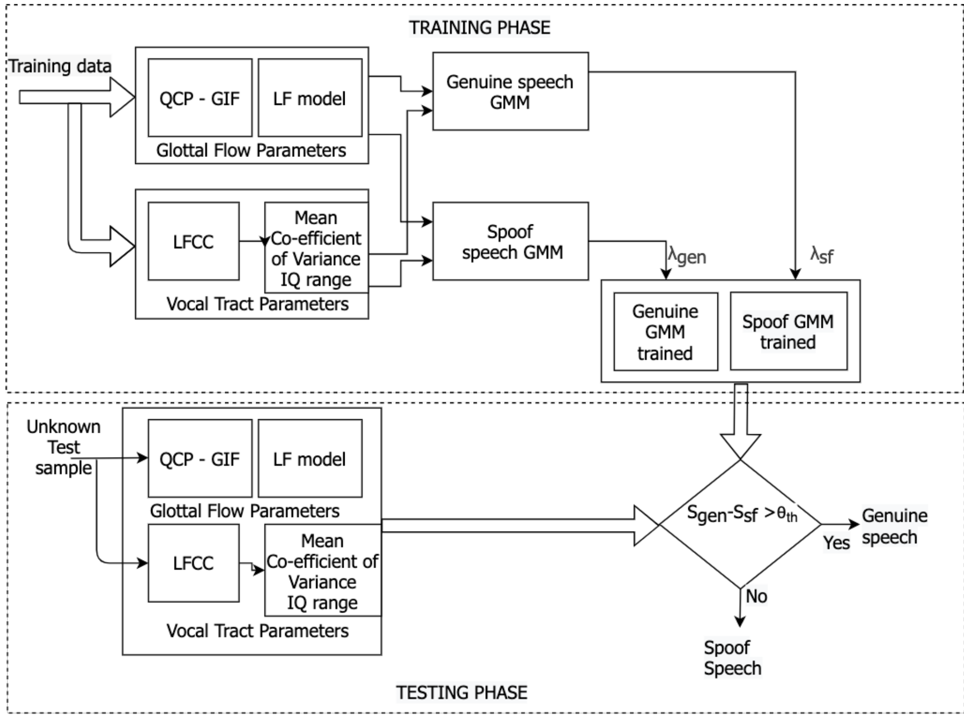


Fig. 3. Block Diagram of Proposed Counter Measure Framework for Automatic Speaker Verification System.

A. Parameterization

During the training stage, the speech samples are low pass filtered along with framing. The silence and pauses at the beginning and end of the sample are removed using Voice activity detection [20]. The VT filter information is represented using LFCC with $20ms$ frame size. Furthermore, the statistical parameters like mean, coefficient of variance (CoV) and Interquartile range (IQR) are combined with the LFCC parameters to form a feature matrix. The LFCC features are found to be more robust than MFCC in terms of noisy speech as it performs well in the higher frequency region (comprising of VT features). The order of LFCC is 19 and its delta and double delta variants are also computed.
The VT filter features alone are not sufficient to represent the speech, especially when the naturally spoken speech needs to be differentiated as against spoofed speech. According to the speech production model, the remaining glottal excitation information is represented using GFP estimation through QCP GIF technique using $30ms$ frame length. The time-based parameters such as OQ, SQ and ClQ are computed in Equation 5:

$$OQ = \frac{(L_{01} + L_c)}{L}, SQ = \frac{L_{01}}{L_c}, ClQ = \frac{L_c}{L} \qquad (5)$$

where, L_{01} is the opening phase length (expressed in time), L_c is closing phase length and L is glottal cycle length which in terms of period. The AQ is computed using Equation 6

$$AQ = \frac{A_{max}}{d_{min}} \qquad (6)$$

where A_{max} is glottal peak and d_{min} is minimum value of derivative of glottal time waveform. The Normalized AQ (NAQ) is given using Equation 7

$$NAQ = \frac{AQ}{L} \qquad (7)$$

Apart from these, the Quasi OQ (QOQ), HRF, Psp and H1H2 are also used as a part of GFP. Additionally, the LF model parameters such as E_e, R_a, R_g and R_k are also considered as they are dependent on the linear source filter model (Table I shows details of parameters). A subjective test is performed (Fig. 4) to discern proficiency of GFP descriptors, box plot analysis is used to display the numerical values of the genuine and spoof speech samples for AQ, QOQ, HRF and H1H2.

From Fig. 4 for AQ and QOQ, it is found that the IQR for genuine and spoof speech are different while for H1-H2 and HRF the IQR values between genuine and spoof speech are slightly similar. Hence, the AQ and QOQ have higher discrimination properties than H1-H2 and HRF.

B. Model Training and Decision Making Algorithm

The GFP parameters, LFCC features, and statistical parameters together form a feature matrix for each sample of the entire data in the spoofed and genuine category individually. In this study, we use the GMM based binary classifier with 512 mixtures for modelling the class labels according to genuine or spoofed speech. The GMM model in case of genuine speech samples λ_{gen} while for the spoofed sample is λ_{sf}. The GMM are considered to capture higher classification accuracy due to their ability to capture generality in case of unknown data samples. For a particular test utterance T, the Log Likelihood

TABLE I. LIST OF DESCRIPTORS BELONGING TO GFP BASED FEATURE EXTRACTION

TIME DOMAIN PARAMETERS	
OQ1 , OQ2	These are Open Quotients computed using Primary and secondary opening of the glottis.
NAQ	Normalized Amplitude Quotient
AQ	Amplitude Quotient
ClQ	Closing Quotient.
OQa	Variant of OQ obtained from LF model
QOQ	Quasi-Open Quotient State
SQ1, SQ2	Speed Quotients These are computed from the primary (OQ1) and openings (OQ2)
TPO	Time corresponding to primary opening
TSO	Time corresponding to secondary opening
TC	Closing time
TMAX	Time corresponding to maximum flow of air pressure
TMIN	Time corresponding to minimum flow of air pressure
TDMIN	Time corresponding to minimum of the derivative
TDMAX	Time corresponding to maximum of the derivative
TQO	Time corresponding to quasi-opening time
TQC	Time corresponding to quasi-closing time
FREQUENCY DOMAIN PARAMETERS	
Psp	Parabolic spectrum parameter corresponds to the second-order polynomial wrt the flow spectrum over a single glottal cycle.
DH12	This is the H1-H2 parameter represented in decibels
HRF	Harmonic richness factor is ratio higher harmonics like f2, f3 etc to f1 (first harmonic)
LF PARAMETERS	
t0	Time corresponding to start of opening phase
tp	Time corresponding to peak of the speech wave
te	Time corresponding to derivative of min peak value
ta	Time corresponding to return phase
Ee	Amplitude corresponding to negative peak of glottal pressure wave in percentage
RA	ta x f0 (where f0 is fundamental frequency)
RG	0.5 f0 x tp
RK	(te-tp)/ tp
OQ	(te + ta) f0
QO	te x f0

Ratio (LLR) is computed from likelihood values of genuine and spoofed speech models. The decision (R) of the test utterance being genuine or spoofed is relying on the LLR as shown in Equation 8

$$R = log(p(T|\lambda_{gen})) - log(p(T|\lambda_{sf})) \tag{8}$$

Where, the likelihood scores obtained from GMM for genuine and spoofed speech samples are $s_{gen} = log(p(T|\lambda_{gen}))$ and $s_{sf} = log(p(T|\lambda_{sf}))$ respectively.

V. EXPERIMENTAL RESULTS

The research is based on ASV spoof 2019 dataset [42] which was the part of ASV spoof challenge held in 2019. The corpus consists of 20 speakers and more than fifty thousand samples in LA attack samples. For training we used 2580 genuine and 22800 spoof samples while 23400 samples are used for development purpose as shown in Table II.

TABLE II. NUMBER OF SAMPLES IN ASV SPOOF 2019 CORPUS FOR TRAINING AND DEVELOPMENT

	Subset	
Logical Access	**Training Data**	**Development Data**
Genuine	2580	2548
Spoof	22800	22296
Total	25380	24844

So far, this is the only dataset with such a wide variety of samples and attack types. The state-of-the-art LFCC-GMM technique is considered as the baseline approach [2]. Furthermore, the process of binary classification leads to two error types: False Acceptance Ratios (FRR) and the False Rejective Ratios (FRR). A standalone spoof detection scheme may falsely reject a genuine sample assuming it to be spoofed or falsely accept an imposter sample assuming it to be genuine. Based on these errors, the DET is used to measure performance of the features used. The operating point obtained from the DET curve is the EER which is another metric for evaluating the spoof detection performance [2]. Lastly, the normalized tandem-Detection Cost Function (t-DCF) [2] is also used to measure performance as it does not require pre-setting of decision threshold and is given in Equation 9

$$norm\ \ t - DCF = p_{FR} + a\ p_{FA} \tag{9}$$

Where p_{FR} probability for scores which are less than set threshold considered as rejected while p_{FA} is the probability for scores which are greater than the set threshold (a) considered as accepted test sample. The ASV and CM scores performance, DET Curve and CM results using EER and t-DCF plots are depicted from Fig. 5 to Fig. 7 and Table III.

The Fig. 5 depicts probability density function (pdf) of ASV and CM scores. The CM scores are for Baseline (red) and the Proposed model (blue). Both models are bimodal except in case of the Proposed model the density has smaller peak in comparison to a more definitive peaks for Baseline model signifying lower pdf for the baseline with two opposite distributions. Fig. 6 and Fig. 7 show the t-DCF and DET curves

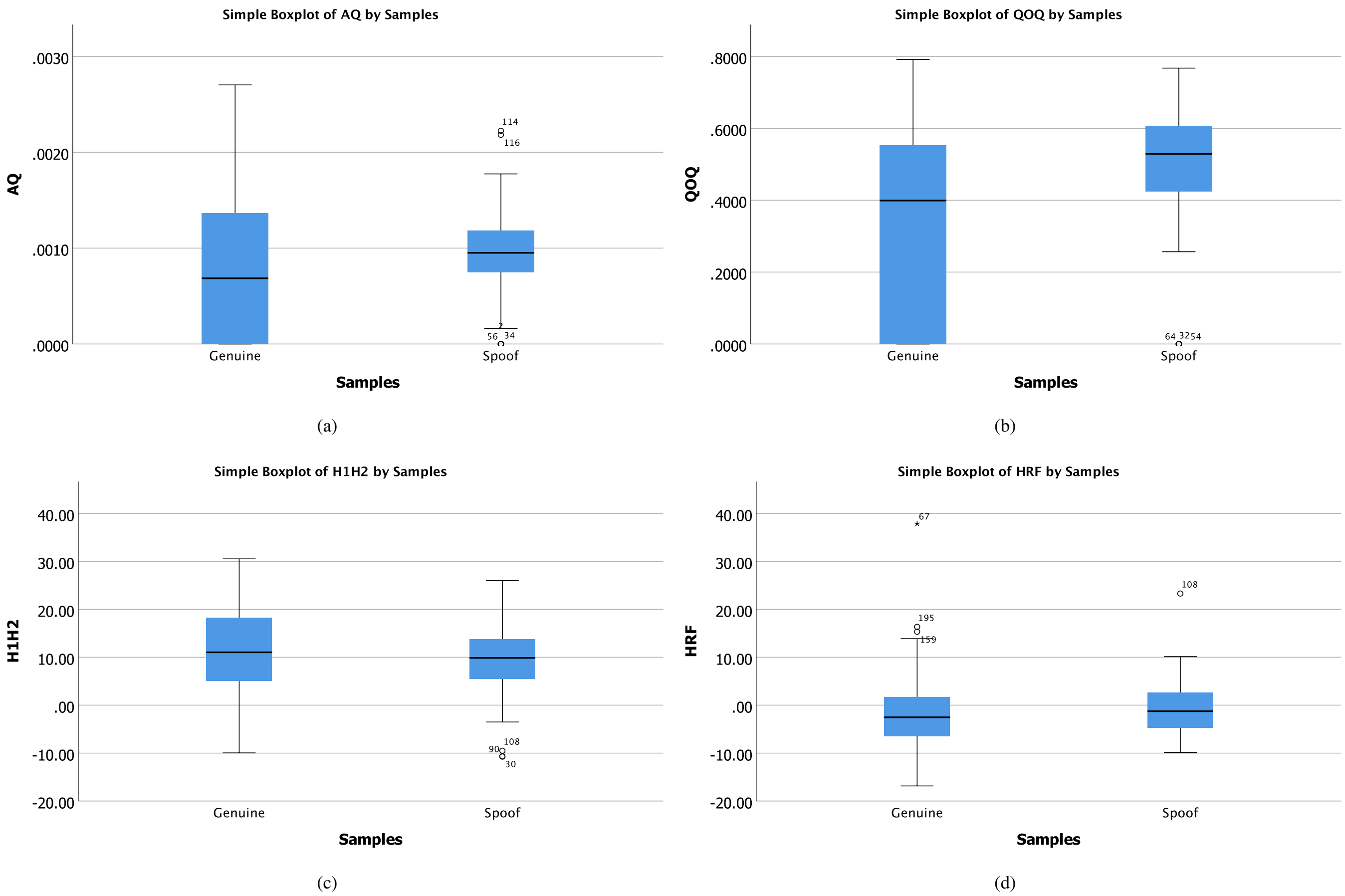


Fig. 4. Subjective Analysis of GFP based Features using ASV Spoof 2019 Dataset for (a) AQ (b) QOQ (c) H1H2 (d) HRF.

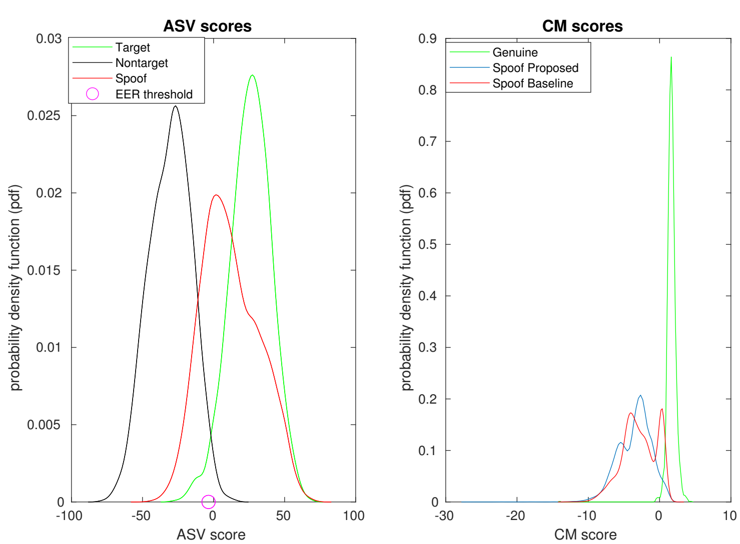


Fig. 5. Probability Density Function (PDF) for Scores of ASV and CM.

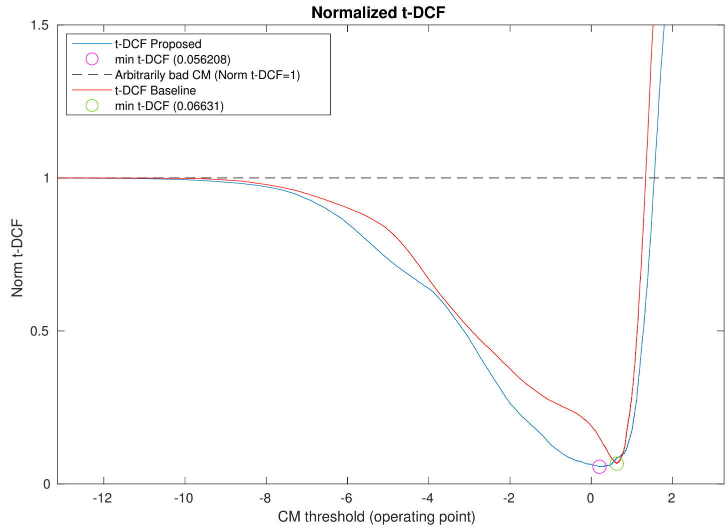
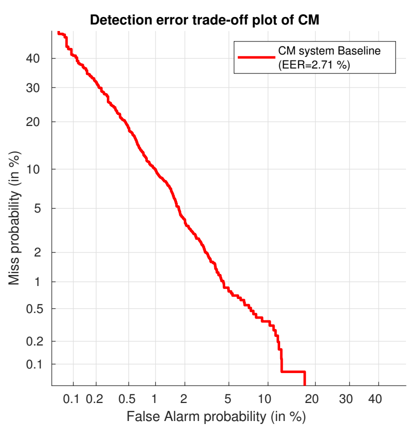
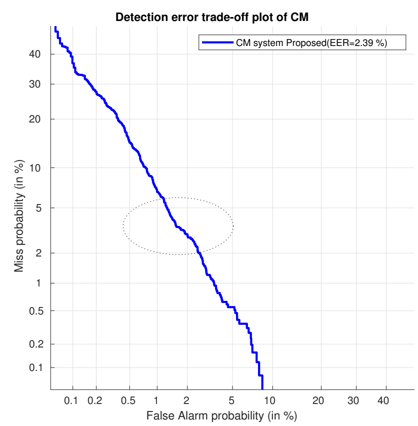


Fig. 6. Normalized t-DCF Plot for Baseline and Proposed CM Algorithm.



(a)



(b)

Fig. 7. DET Curve for (a) Baseline CM (b) Proposed GFP CM.

respectively. The t-DCF is lower for proposed technique in comparison to the baseline model. Also, the DET curve shows slightly lower EER for proposed technique in contrast to the baseline method (shown in Table III).

TABLE III. EER AND NORMALIZED T-DCF SCORE FOR BASELINE AND PROPOSED TECHNIQUE

CM type	EER %	t-DCF
Baseline LFCC -GMM	2.708	0.066
Proposed GFP+ LFCC+ stats -GMM	2.390	0.056

VI. DISCUSSION

The GFP-based features are unique and not much explored in the spoof detection domain. The Glottal-flow plots for synthetic speech highlight the significant difference in the amplitude, time, and frequency information from the genuine speech. This ascertains the importance of proposed GFPs in addition to VT parameters in developing countermeasures. Also, the selection of the right GFPs is crucial. Thus, we plotted the box plot to investigate which parameters are more reliable than the others. For instance, the AQ captures the glottal peaks accurately and due to the synthetic nature of spoofed speech, the amplitude information is found to be deviating from genuine speech. While on the other hand, the HRF represents the quality of speech which may perceptually similar. Hence, detecting spoofed speech from genuine is slightly difficult with HRF and similar parameters. In contrast, the GFPs on the whole when used in the conjunction with VT parameters show improvement in the EER and t-DCF when compared to the baseline technique. This might be due to the fact that missing glottal flow information is now fulfilled by the 31 QCP Glottal features that represent amplitude along with with time-frequency contents; and also due to the fact that the high pitched voices are now easily detected with these proposed GF features leading to better results.

VII. Conclusion

The main role of a counter measure is to prevent any unauthentic access. For doing so, the kind of attack and spoofed speech must be analysed. Hence, in this research, we focused on the synthetic speech attack using unique QCP estimation for extracting GFP from both genuine as well as spoof speech. Since, the GFP represents the source of attack samples, the minute differentiation between genuine and spoof speech was magnified with GFP. As a result, GFP certainly added the information contents to the features set by further reducing the EER from 2.70% for Baseline LFCC to 2.39%. So, the FAR and FRR can be reduced by extracting relevant information from spoofed speech. Additionally, the GMM classifier captured the non-linearities quite well as the conjugative contribution of GFP and LFCC provided sufficient data for better classification accuracy. Also, this research can further be extended for replay speech where noise based artifacts may be present and GFPs are found to perform significantly well in noisy speech. In addition to the improvements obtained by employing the QCP based GF parameters, there are two prime limitations of these features: first, the QCP based GIF requires precise estimation of GCI. This can be explored in the future by investigating more appropriate GCI estimation techniques. Secondly, the unstable filter parameters contribute to computational complexity while extracting these features. From future prospects, the prosodic features may be explored in conjunction with source filter parameters for further reducing the EER and improving the countermeasure performance.

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Knowledge Base Driven Automatic Text Summarization using Multi-objective Optimization

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Abstract—**Automatic Text summarization aims to automatically generate condensed summary from a large set of documents on the same topic. We formulate text summarization task as a multi-objective optimization problem by defining information coverage and diversity as two conflicting objective functions. With this formulation, we propose a novel technique to improve the performance using a knowledge base. The main rationale of the approach is to extract important text features of the original text by detecting important entities in a knowledge base. Next, an improvement on the multi-objective optimization algorithm is also proposed for the automatic text summarization problem. The focus is on improving efficiency of the each steps in the evolutionary multi-objective optimization process which is applicable to all tasks with the same problem formulation. The result summary of the suggested method ensure the maximum coverage of the original documents and the diversity of the sentences in the summary among each other. The experiments on DUC2002 and DUC2004 multi-document summarization task dataset shows that the proposed model is effective compared to other methods.**

Keywords—Multi-document summarization; evolutionary multi-objective optimization; knowledge base; named entity recognition

I. Introduction

As text information publication speed outgrows our consumption capability, there have been many approaches to deal with the information overload problem suggested by the research community, such as information retrieval [1], semantic web [2], and text summarization [3]. While the results are, to some extent, successful and promising, we still need to deliver the text content efficiently so that the readers can consume more qualitative content within a limited amount of time.

The goal of this paper is to propose a generic, extractive, and multi-document summarization method. Each of these summarization types has an alternative approach, namely, query-focused, abstractive, and single-document summarization. As opposed to a generic summarization, some keywords are provided for a query-focused summarization task. The summarizers proceed with the summarization using the query term as a guide. Extractive summarization task composes a summary with unaltered sentences selected from the original document set, which is distinguished from an abstractive summarization task where sentence modification or phrase selection and generation are allowed.

To solve a generic extractive summarization problem, the authors propose a model using evolutionary multi-objective optimization. Multi-objective optimization approach to a text summary generation task is gaining attention recently from the research community [4], [5], [6]. Previous research directions mainly focus on applying and testing diverse optimization methods within the multi-objective problem formulation. Here, we begin the discussion by setting the goal as how to define a robust objective function. The objective function suggested in this paper evaluates all the sentences in a document set as a whole, as opposed to a local evaluation approach which evaluates each sentence one at a time causing local optima entrapment. There are many ways to define objective functions. In this research, the main objective functions are the coverage and the diversity functions. Although many other methods use a simple coverage function, we claim that improving the coverage function is especially important. From this perspective, we propose a method on how to utilize the knowledge base which encodes how human thinks and what is important.

The method to calculate the objective function values relies on multiple text mining techniques including term weighting scheme, similarity measurement function, text preprocessing, and Named Entity Recognition (NER). The objective function evaluations are continuously performed based on these techniques as the optimization progresses. The proposed objective functions are based on coverage and diversity evaluations. While these concepts were individually dealt with in other text summarization approaches [7], [8], [9], considering them as two objective functions within a coherent multi-objective optimization framework provides a power to adopt many other improvement strategies, not limited to the specific evaluation concept in question. On top of this framework, the authors suggest a novel knowledge-based named entity topic construction approach for a robust objective function development. The rationale behind the proposed approach is that document summarization can be seen as a multi-objective optimization problem, defining the objective functions to reflect the characteristics of well-generated summaries. Such an optimization task requires binary encoding of data, and assigning one bit for each sentence fits the extractive summarization task. Maximum content coverage and maximum content diversity are deemed equally important and at the same time conflicted. Hence, the problem is modeled as a multi-objective optimization using the two conflicting objective functions.

In this research, we use a high-performance evolutionary multi-objective optimization method Non-dominated Sorting Genetic Algorithm II(NSGA-II), and propose an adaptive NSGA-II for a text summarization task. The technique is a state-of-the-art algorithm for multi-objective optimization tasks producing a population of possible solutions as opposed to single-objective optimization algorithms which can only provide a single solution. The algorithm adds more flexibility to the proposed method as a user can generate as many equally optimal summarizations as one needs by increasing the population size.

We first review previous approaches in the text summarization domain. Then we argue that adopting a multi-objective optimization technique combined with a knowledge-based approach shows a state-of-the-art summarization result.

For a thorough comparison, Document Understanding Conference 2002 (DUC2002) and 2004 (DUC2004) multi-document summarization (MDS) task dataset are used as an evaluation source, and the comparisons are done against multiple methods in the literature including non-optimization-based and optimization-based methods.

The next section details related work from past studies. Section III explains how the text summarization problem is formulated into a multi-objective optimization. Section IV explains how the knowledge-based coverage objective function is defined and calculated. Section V explains the multi-objective optimization and the details on the improvement of the NSGA-II optimization method when applying to the text summarization problem. Experiment results are shown in Section VI with a comparison against past studies. The last Section VIII discusses the results and possible future research opportunities.

II. Related Work

In this section, we present a review of the main research fields related to text summarization and optimization. The research on text summarization started in the late fifties [10]. Automatic text summarization is a complex and challenging task ranging over multiple domains of research. There are many issues to consider when generating a summary from multiple documents, such as coverage, diversity, redundancy, temporal dimension, co-reference, sentence ordering, synonymy, and so on. The focus was on the single document summarization at this stage. Researchers started to focus on an MDS problem in later years [11]. Goldstein et al. [12] suggested extraction of sentences from multiple documents approach on top of single-document summarization techniques.

Text summarization can be grouped into two types of tasks. Abstractive summarization aims to generate a new set of informative sentences by utilizing existing phrases [13], [14]. The set of concepts are usually extracted from the given document dataset. Then summarization is automatically written with the selected noun and verb phrases in the conformation of sentence construction constraints and saliency-maximized order. However, abstractive summarization methods generate non-fluent summaries and have high computational complexities; their performance improvements mainly comes from the improvements of other research fields, such as integer linear programming methods and grammatical sentence formulations [14]. On the other hand, the research on extractive MDS was focused on how to select the most relevant sentences to be included in the summary. The extraction and representation of the topics included in the original documents are two of the important issues in this area [15]. Reducing redundancy and maximizing diversity in the generated summary is key to the summary generation task, therefore these are the two objectives that most MDS techniques consider important.

There are numerous other research on redundancy reduction with extractive MDS. Sarkar [16] used local and global trimming rules to tackle the redundancy problem. Carbonell et al. [17] utilized both query-relevance and information-novelty, using the Maximal Marginal Relevance(MMR) to reduce redundancy while preserving query relevance for the summarization. Using an unsupervised approach, Zha [18] explicitly modeled the key phrases and the sentences that contain them. The model is represented as weighted undirected and weighted bipartite graphs to extract the sentences without going through an extensive training phase. Centroid-based summarization has shown success in many past works in redundancy reduction as well. The earlier research suggesting a centroid-based approach for MDS [19] relies on TF-IDF term weighting scheme to measure the centrality of the sentences by comparing the similarity of the sentences to each cluster centroid. LexRank [20] is later suggested where they first represent a graph of sentence relations by using intra-sentence cosine similarity and calculate eigenvector centrality of the sentences. Their main contribution is to measure sentence centrality based on the sentence relations rather than relying on cluster centroids. They assume that sentences with more similar sentences are considered to be more central. Biased LexRank [21], a semi-supervised method on pairwise lexical similarity sentence graph, is later proposed to use both intra-sentence and inter-sentence similarities for the task. The method allows topic, or query, sensitive sentence retrieval with weighted random-walk based on a prior distribution of sentence ranks, performing well on both extractive text summarization and passage retrieval tasks. StarSum [22] focuses more on the intra-sentence similarities and proposes a star-shaped sentence - topic bigram bipartite graph to emphasize intra-sentence topic discrepancy, representing each sentence as a collection of topic phrases. On top of intra-sentence and inter-sentence similarities, intra-document sentence similarity distinguished from inter-document sentence similarity allows Document-Sensitive Ranking (DsR) [23] algorithm to treat multi-documents as individual documents with different topics and information rather than one large document. DsR algorithm utilizes document-sentence and document-document links as well as sentence-sentence links showing top performance on both the DUC2004 and DUC2007 dataset.

There are a number of other MDS research utilizing graph-based approaches. Cluster-based conditional Markov random walk [24] model overcomes the limitation of directly applying Markov random walk on MDS fields, differentiating sentence clusters (thematic representation of a document) with varying size and importance as well as weighting intra-cluster sentences based on to-centroid distance. The authors also propose a cluster-based hyperlink-induced topic search (HITS) model to analyze graph link in different perspectives and show both models perform well on the DUC2001 and DUC2002 dataset. iSpreadRank [25] aims to improve the sentence ranking phase of extractive MDS task with the concept of spreading activation theory. The method recursively spread sentence-specific scores to their neighbors in the graph model of document sentences, allowing utilization of neighbor importance as well as neighbor counts when ranking individual sentences. Generic summary methods tailored to iSpreadRank are tested on the DUC2004 dataset, with the best performing variant having 0.38068 ROUGE-1 score better than the second-best system. Centrality is an importance measure for an individual node within a graph. Introduction of super-vertices to the sentence graph each representing subset of sentences within a document set allows the calculation of super-centrality, an importance measure for the super-vertex hence sentence group to the document set [26]. This allows a robust non-redundant sentence selection compared to the existing MMR method and shows performance improvement over the aforementioned LexRank method. More generic graph-based framework applicable to all generic, query-based, update, and comparative MDS tasks is proposed based [27] on using the minimum dominating set, a minimum subset of a graph where every vertex in the graph is either member or neighbor of it, as a basis for the document summary. Other graph-based MDS research includes semantic linkage analysis, where relationships between sentences are measured by their semantic relationships [28]. Sentence fusion technique [29], including bottom-up local multi-sequence alignment, is proposed to shift the MDS research field from extractive summarization tasks to abstract summary generation tasks as well.

Clustering-based approach is also proposed to deal with MDS where documents and in turn their sentences are clustered together by using features such as cosine similarity, and sentences with best scores within each cluster are retrieved to form a summary [30]. Clustering on extractive MDS task works in three steps; sentence clustering, ordering, and cluster representative sentence selection. Histogram based clustering, content-word weight-based cluster ordering, and local/global word importance-based sentence selection shows ROUGE-1 score higher than the second-best system of the DUC2004 in task 2 [31]. Term-vector based document clustering, feature profile based sentence selection from clusters followed by chronological ordering creates summaries with higher sentence scores compared to a centroid-based clustering algorithm and showed it can extract relevant sentences across multiple documents [32]. Jung et. al. [5] was the one of the early research that proposed topic-based MDS using multi-objective optimization. Here the topics are defined as clusters of terms.

Several interdisciplinary research is done on the topic of MDS, and the use of topic modeling is one of them. Probabilistic latent semantic analysis (PLSA) on sentence-level topic distribution produced three variants of query-focused extractive summarization method all of which showed high ROUGE-1, ROUGE-2 and ROUGE-SU4 scores on a par with best reported on the DUC2006 and DUC2007 [39]. The Pyramid method [40] is a manual evaluation approach opposite to the commonly used ROUGE [41] method, evaluating automated summaries against human-annotated summaries. Hennig [42] further expanded on unsupervised semantic analysis on text units by mapping topic models towards summary content units used with the Pyramid method, proving a trained probabilistic topic model exhibit structures similar to the human model summaries. The use of the term-document matrix is proposed to overcome the semantic limit of the term-sentence matrix commonly used in existing MDS methods to realize hidden topics embedded within the document collection themselves. Bayesian sentence-based topic models (BSTM) [34] uses both term-sentence and term-document matrices to build document-sensitive sentence topic models and show higher ROUGE scores than six existing summarization method, nearing the scores of the best team in both the DUC2002 and DUC2004. Numerous multidisciplinary research is done on topic models for MDS. Fuzzy logic, in combination with a topic model, showed that the topic words can be replaced with fuzzy elements to build a fuzzy inference summarization system producing automated summaries focusing on divergence and similarity [43]. Distributed processing framework such as MapReduce is also proposed to overcome the computing intensity of MDS using topic modeling, nearly halving the computation time with four nodes when the dataset grew up to 3890 documents [44].

Deep learning based approaches are getting attention recently. Most of the recent state-of-the-art performance models for the NLP tasks are based on Pre-trained Transformer-based [45] deep neural network models such as BERT [46]. Deep learning models are applied to extractive sumarization task as shown by Liu [47]. Computing a feature space of sentences from a single document with deep auto-encoder (AE) is reported to improve the feature space recall by 11.2% on average [48]. The approach uses an ensemble noisy auto-encoder (ENAE) which aggregates sentence selection over multiple runs by adding random noise to the word vector, allowing more robust behavior even with a smaller vocabulary.

Summary optimization is a more recent approach to MDS. One of the key features dictating clustering performances in this approach is its criterion or objective function. A differential evolution algorithm is proposed [49] to optimize an objective function of clusters found by normalized google distance (NGD) [50], where each candidate sentence is represented as a gene in a chromosome with the number of clusters as its value range. A self-adaptive differential evolutionary algorithm is applied to redundancy in MDS with the optimization goal of reducing semantic redundancy in summary sentences. Sentence scores are measured based on other sentences within a summary guaranteeing both diversity and coverage to be measured as a discrete optimization problem, which is mediated by the introduction of self-adaptive crossovers within the DE algorithm [9]. The use of optimization and machine learning technique on document summarization is one of the main approaches to the MDS problem while relatively new compared to statistic-based methods. Multi-objective optimization(MOO) on MDS is a lesser studied variant of optimization-based MDS where multiple summaries with equal overall quality can be produced by mediating multiple, often conflicting, quality measures. Huang et al. [51] proposed MOO modeling of MDS to overcome sentence redundancy problem in single-objective optimization approach, as well as information coverage, significance, and text coherence. Artificial bee colony optimization [6] method modified with multi-objective capability is used on MDS to show that the approach can be used to enhance the performance of existing work by incorporating both sentence coverage and redundancy as optimization objectives. Sekaran et. al. [52] combined Information Retrieval technique with text summarization to better serve human information needs.

TABLE I. LIST OF DOCUMENT SUMMARIZATION METHODS TO COMPARE

Topic	Main characteristics of the method	Use of coverage or diversity
2001, LSA[7]	Latent Semantic Analysis	coverage & redundancy
2004, LexRank[20]	Graph-based method	
2004, Centroid[19]	Centroid-based method	
2009, NMF[33]	Non-negative Matrix Factorization	
2009, MCKP[8]	Knapsack problem solving using greedy algorithm	coverage
2009, BSTM[34]	Bayesian Sentence-based Topic Model	
2011, FGB[35]	Kullback-Leibler divergence, Factorization with given bases	
2012, WCS[36]	Weighted consensus scheme	
2013, OCDsum-SaDE[9]	Single-objective optimization	coverage & diversity
2016, GO[37]	Genetic-based optimization	coverage & redundancy
2017, CRSum[38]	Contextual Relation-based, Neural Network Model	
2018, ABCO[6]	Artificial bee colony optimization	coverage & redundancy
DUC	Best result of the participants in the DUC	
Random	Random summary selection strategy for a baseline	

Among diverse approaches to tackle the problem of extractive summarization, there are some advantages of multi-objective optimization method. From the practical perspective, it is sometimes more useful to generate multiple alternative summaries rather than single result summary. One of the advantages of the proposed approach is that it produces multiple non-dominating solutions where a person can choose to select a final solution with varying properties after the multiple candidate solutions are generated. In the case where one final solution is required, the authors suggest a solution selection strategy amongst the multiple summaries. This feature provides higher generalizability to the proposed method, granting utility in the research, industrial, and personal aspects. Additionally, multi-objective summarization provides users more choices to select summarization based on combinations of various – and possibly conflicting – characteristics, such as coverage and diversity. In the context of an interactive environment where people can interactively read multiple summaries, the multi-objective optimization can offer various candidates for users to select from. This cannot be achieved by single-objective summary generation methods. Table I shows the list of methods we compare to including their use of either coverage or diversity as a feature.

III. PROBLEM STATEMENT

We formalize the text summarization problem as an optimization problem. The goal of the extractive text summarization task is to select the sentences that reflect the original text as much as possible within the given length. A basic approach is to evaluate the sentences individually and select the ones that satisfy a set of predefined criteria. However, this localized approach may suffer from the selected sentences failing to cover the whole content of the original text. The advantage of the optimization approach is that the evaluation is performed as a whole for a set of selected sentences. This allows our approach to overcoming the weakness of the previously described basic approach. The proposed model consists of two large modules continuously working together throughout the optimization process to generate the Pareto optimum summaries. The optimization module is in charge of optimizing the two objective functions using evolutionary multi-objective optimization, and the text processing module accepts the binary-encoded candidate summaries and returns calculated objective function values. Objective function calculation is normally evaluated by solving the algebra equation. The separate text processing module is necessary for this research because the objectives can only be calculated by going through a complicated text processing process including several steps of preprocessing and similarity computation.

A. Text Similarity Model

Throughout the automatic text summarization process, the similarity measurement between two text segments is constantly performed. This is a basis for a high-quality summary. In the proposed method, the most widely used cosine similarity measure is adopted. Cosine similarity measures how much the two given sentences are similar in a term vector space. For this purpose, we represent our text segments using a Vector Space Model(VSM). VSM is a way to represent a text as a vector so that any text segment can be represented in a coherent vector space without considering the order of the terms in the original text. By representing each sentence using VSM, we can use many methods that do not consider term order, such as the cosine similarity measure. If we consider the term order when comparing the sentence similarity the two pieces of sentences that contain similar content may be given a very low score which is not appropriate for our purpose.

For the two objective function calculations, we use cosine similarity as a similarity function. Our main idea is to utilize the power of the binary multi-objective optimization algorithm to the full extent on a text summarization problem. For the algorithm to deal with the text units, we represent any set of sentences as a binary vector. Thus, both a document and a generated summary are fixed-length binary element vectors with the length being the total number of sentences in the document set D. Since we are dealing with multi-document problem, let $D = \{d_1, d_2, ..., d_N\}$. N is the total number of documents that exist in corpus D. As we deal with a sentence as a summarization unit, the document set D is also defined in terms of sentences and defined as $D = \{s_1, s_2, ..., s_n\}$, where n is the total number of sentences in the original document set and $s_i \in \{0, 1\}$. $T = \{t_1, t_2, ..., t_m\}$ represents all the unique terms that appear in document corpus D. This is our vocabulary to be used and a corpus of documents contain m unique terms.

Each sentence consists of a list of terms, shown as a list of real number weights each representing the importance of the term. There are many ways to assign weights to the terms in a sentence. In this paper, we use a modified TF-IDF term weighting scheme which is widely used for text mining tasks. The basic unit of selection is a sentence in this research and the inverse frequency is calculated per sentence instead of per document. In this formulation, a term weight is defined as:

$$w_{ik} = tf_{ik} \cdot isf_k \tag{1}$$

w_{ik} is a weight for term t_k in sentence s_i. tf_k is the number of occurrences of term t_k in sentence s_i. $isf_k = log(n/n_k)$, where n_k is the number of sentences that contains the term t_k. isf_k is calculated by the sentences frequency n_k divided by the total number of sentences n. With this weighting scheme, i_{th} sentence s_i is represented as $s_i = \{w_{i1}, w_{i2}, ..., w_{im}\}$ where m is the total number of terms in the document collection. w_{ik} is a weight value for k_{th} term in i_{th} sentence.

Cosine similarity measures how much the two given sentences are similar. For the two objective function calculations, we use cosine similarity as a similarity function. Let s_i and s_j be the two sentences to be compared, where m is the total number of distinct terms in the document collection. Cosine similarity between the two sentences is defined as:

$$sim(s_i, s_j) = \frac{\sum_{k=1}^{m} w_{ik} w_{jk}}{\sqrt{\sum_{k=1}^{m} w_{ik}^2 \cdot \sum_{k=1}^{m} w_{jk}^2}}, \quad i, j = 1, 2, ..., n. \tag{2}$$

B. Problem Formulation using Multi-objective Optimization

From Section 2, we can observe that most of the research work in MDS considered information coverage, diversity, and a weighted combination of both. These are contradictory goals as often are in most decision-making situations, as higher information coverage ensures a more informative summary whereas higher diversity results in less redundant information in the outcome. These two goals cannot be obtained with a single optimization task. As a result, a contradiction between information coverage and diversity is modeled as a multi-objective optimization problem. Their contradiction tendencies can be shown when the summary size changes; the coverage increases while the diversity decreases when more sentences are extracted for the summary.

The main purpose of multi-objective optimization is to identify all non-dominated solutions that are different from each other and hold equal importance. These solutions provide more flexibility to the complex problem compared to the outcome of single-objective optimizations, as any solution can be chosen to satisfy the specific requirements of the user. NSGA-II [53] is used to produce non-dominating solutions by considering the conflicting objectives. When a single solution is required, we select the Pareto optimal solution with the maximum coverage as our final summary.

The mean vectors of the original document set and the solution summaries are compared to allow the similarity comparison independent of the solution length. Sentence by sentence comparison will result in a biased similarity measure, where solutions with more sentences receive higher scores when compared to the whole set. The center of sentences in the given vector set is used instead to remove the number of sentences during the calculation, where the similarity is measured term by term instead. Mean vector $o = [o_1, o_2, ..., o_m]$ is used to represent a center of a set of sentence vectors in the original document set D, and the mean summary vector $o^s = [o_1^s, o_2^s, ..., o_m^s]$ represents a center of a set of extracted sentence vectors and is used to compare the similarity between o and the solution summary. Each element for the kth term is defined as:

$$o_k = \sum_{i=1}^{n} w_{ik}, k = 1, 2, ..., m. \tag{3}$$

$$o_k^s = \sum_{i=1}^{n} w_{ik} \cdot x_i, k = 1, 2, ..., m. \tag{4}$$

o and o^s are used in the coverage objective function calculation, where the differences between the original set D and the solution summary $\bar{D}$ is given by the inclusion variable $x_i \in \{0, 1\}$, which is a binary variable representing whether a sentence s_i from D is selected to be included in $\bar{D}$. The coverage objective function is to evaluate the similarity between the summary and the original document set and is defined as:

$$f_{coverage}(\mathcal{X}) = sim(o, o^s) \cdot \sum_{i=1}^{n} \frac{sim(o, s_i) \cdot x_i}{n} \tag{5}$$

We normalize the summation of the similarity values to mitigate the bias towards including more sentences with fewer terms. Otherwise, the summary will be biased towards including shorter sentences.

The diversity objective function is defined as Equation 6. There is another similar concept called redundancy in the literature. The difference between the diversity and the redundancy is that redundancy is calculated as the sum of cosine similarity, whereas the diversity is calculated as the sum of cosine distance, where $cosine\_distance = 1 - cosine\_similarity$.

$$f_{diversity}(\mathcal{X}) = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \frac{(1 - sim(s_i, s_j)) \cdot x_i \cdot x_j}{n \cdot (n-1)} \tag{6}$$

IV. Knowledge based Driven Keyword Extraction

A. Knowledge Base

Defining an objective function that highly reflects how human summarizers perform is a guide to finding successful solutions using an evolutionary algorithm. To improve the basic coverage function defined in Section III, we utilize human knowledge and incorporate it into our coverage objective function. The proposed knowledge base driven text summarization relies on entity information encoded in an underlying knowledge base. As the term knowledge base driven implies, the coverage objective function we propose guides the optimization process towards the near-optimal solutions regarding human cognition. In this work, we use DBpedia as our source knowledge base and DBpedia-spotlight as an interface to annotate a text. DBpedia [54] is a knowledge-base

TABLE II. EXAMPLE TEXT SNIPPETS FROM TOPIC D061 OF DUC2002 DATASET AND THE TYPES

Example: "The **National Hurricane Center** said a hurricane watch was in effect on the coast from **Brownsville** to **Port Arthur** and along the **coast** of northeast **Mexico** from **Tampico** north. The National Hurricane Center said Gilbert was the most intense storm on record in terms of barometric pressure."

Detected Entity Term	DBpedia type	Freq
National Hurricane Center	DBpedia:Agent	85
	DBpedia:Organisation	49
	DBpedia:GovernmentAgency	16
coast	DBpedia:Place	259
	DBpedia:Location	259
	DBpedia:PopulatedPlace	226
	DBpedia:Settlement	89
Brownsville	DBpedia:Place	259
	DBpedia:Location	259
	DBpedia:ArchitecturalStructure	14
	DBpedia:Infrastructure	6
	DBpedia:Station	1
Port Arthur	DBpedia:SocietalEvent	13
	DBpedia:Event	13
	DBpedia:MilitaryConflict	12
Mexico	DBpedia:Place	259
	DBpedia:Location	259
	DBpedia:PopulatedPlace	226
	DBpedia:Country	102
Tampico	DBpedia:Place	259
	DBpedia:Location	259
	DBpedia:PopulatedPlace	226
	DBpedia:Settlement	89

where the community has put an effort to extract structured information from Wikipedia. In the proposed method, the type information of the entities in DBpedia are used for the knowledge base driven approach, where the term frequencies show reverse correlation to the term specificity; types with a high type frequency are more general, while less frequent types have a more specific meaning. The words with a low type frequency have more significance unlike that of the tern frequency, as their specificity leads to higher chances of them having more important roles in the context of the text. Note that each term may be included in multiple types. Any knowledge bases such as YAGO [55] ontology can be also used for this purpose, and DBpedia Spotlight [56] was used for our knowledge-based NER.

Most of the statistical approaches such as TF-IDF rely on the frequency of the terms. However, this may suffer from rare but important terms being assigned a lower weight value. Knowledge base driven method overcomes this missing low frequency, high importance terms by relying on the source that explicitly encodes this information. It is often the case that the knowledge bases and knowledge graphs are used in a complex entity detection and graph matching of semantic information. Although the complicated methods are very useful in certain cases, the proposed method utilizes the encoded information embedded in the knowledge base during the knowledge base construction. Since knowledge bases are constructed based on the ontology reflecting human thoughts, the types represented in the ontology and the entities that belong to those types are a gist of human knowledge encoded for the computers to access and mirror human intelligent behavior. The proposed method makes use of this explicitly encoded information to detect the keywords. The keywords we use are the Named Entities. As we can see from the other research on NER, detecting the named entities can boost the performance of any model that relies on NLP technology.

Table II shows an example of DBpedia types that can be linked to the terms in the example text. The raw text column contains the NER result based on the DBpedia knowledge base. DBpedia type column lists the types linked to the entities after linking it to the KB using NER. The number shows the occurrence of each type in the corresponding topic. We can see that there can be multiple types linked to each entity. Table II shows that the knowledge-based named entity keyword extraction and topic construction can give higher importance weights to the rare but infrequent terms.

B. Topic Analysis

The necessity of adopting the type of topics for the coverage objective function comes from the bias that may exist in the similarity value aggregation. A term or a sentence level comparison for the text similarity may suffer from a preference bias towards the sentences that cover more range of available terms. If the original document set has many terms describing the same topic, the generated summary has a higher chance to include redundant content. Term and sentence level similarity calculations on the detected topics are done to mitigate the original document's bias towards a small portion of topics.

C. Knowledge based Driven Coverage

Algorithm 1 Knowledge Base Named Entity Extraction.

INPUT: Threshold θ
OUTPUT: Key Entity SET(KES): K
Initialize K, T
for each $d \in D$ **do**
    for each $s \in d$ **do**
        for each $t \in s$ **do**
            if $t \in E$ **then**
                T.add(DBpediaTypeOf(t))
Sort C by count in decreasing order
$\bar{T} \leftarrow$ lower θ percent of T
for each $d \in D$ **do**
    for each $s \in d$ **do**
        for each $t \in s$ **do**
            if $DBpediaTypeOf(t) \in T$ **then**
                K.add(t)
return K

The process of knowledge base driven named entity extraction is based on the algorithm shown in Algorithm 1. This process extracts the Key Entity Set(KES) and constructs topics from the result. The proposed model first performs named entity detection using a knowledge base. As described earlier, from using knowledge bases, we can also acquire type information from the entity. The types can be seen as an abstract layer of the terms. After the NER, we extract the types of the detected entities. The types collected are defined as T. Then, we filter out the common types using a threshold parameter θ to extract θ percent of least-frequent types. By removing the common types, we can learn the rare but important entities of those type set. From the filtered type set T, a set of terms included in those types from the target text document is collected. This is a Key Entity Set(KES) defined as K. KES is considered as a virtual topic, namely, Named Entity Topic(NET). After NET is collected, we consider these terms the same as normal terms explained in Section III. Based on KES, the improved coverage objective function is defined similarly using TF-IDF weighting scheme and cosine measure based on the coverage objective function defined in Section 5.

D. Knowledge Base Driven Coverage

In this section, we define the knowledge base driven coverage function $f_{coverage-k}$ using the KES explained earlier. Mean entity vector $\mu^s = [\mu_1^s, \mu_2^s, ..., \mu_m^s]$, is used to compare the similarity between the mean document vector o and the constructed topics. The topics are constructed from the named entities that exist in the knowledge base. We have defined Key Entity Set(KES) and Named Entity Topic(NET). NET if constructed from KES using a Knowledge base NER. The detailed steps are explained in Algorithm 1. Each mean vector of NET for document d is defined by:

$$\mu_k^s = \sum_{i=1}^{n} w_{ik} \cdot y_i, k = 1, 2, ..., m. \tag{7}$$

where $y_i \in 0, 1$ is a binary variable that represents whether a term t_i is in KES. Now the improved knowledge base driven coverage objective function $f_{coverage-k}$ is defined as follows:

$$f_{\text{coverage-k}}(\mathcal{X}) = sim(o, \mu^s) \cdot sim(o, o^s) \cdot \sum_{i=1}^{n} \frac{sim(o, s_i) \cdot x_i}{n} \tag{8}$$

V. Adaptive Multi-objective Optimization for Text Summarization

A. Non-dominated Sorting Genetic Algorithm (NSGA-II)

Developed as an improved version of NSGA, NSGA-II has been one of the best performing multi-objective optimization algorithms since its inception in 2002 [53], having been applied to diverse areas such as engineering, computer science, biology, and economics. It generates a population of individual solutions to obtain a set of approximated Pareto-optimal solutions. The algorithm improves the non-dominated solutions in each iteration till it can achieve the least erroneous set of non-dominated solutions. There are two main operators involved in the foundation of NSGA-II. These two operators are crowding distance and non-dominated sorting. Out of these two operators, crowding distance is used to guarantee a set of diversified solutions in the whole search space. On the other hand, non-dominated sorting is used to select the best solutions from crossover and mutation by disposing of the solutions worse than other population members. These two operators are also responsible for ranking both dominated and non-dominated solutions.

The first step of NSGA-II is the generation of N population members, which are randomly generated based on the given lower and upper variable bounds. Thereafter these N population members are sorted used a non-dominated sorting algorithm. The new child solutions are formed with two genetic operators known as crossover and mutation. After this step, the N parent and child population are coupled together to create a combined population of size 2N. Then N non-dominated solution members are selected from them using the non-dominated sorting algorithm. Thereafter, crowding distance is obtained to discard the low-density solutions which are the solutions that are closed to each other. These steps are continued till the maximum number of generations specified by the user is reached or the termination criteria are met.

Algorithm 2 Adaptive NSGA-II for text summarization.

```
INPUT:  n ≥ 0 ∨ x ≠ 0
OUTPUT: y = x^n
Adaptive Initialization
Generate non-dominated population P_0 of size N
Compute the objective function values of the initial population
Adaptive Mutation
Adaptive Crossover
Generate children population Q_s of size N
while i ≤ i_max do
    Merge parents and children while maintaining ellitism(R_i = P_i ∪ Q_i)
    Fast non-dominated sorting algorithm(non-dominated Pareto fronts F_1, F_2, ..., F_k in R_i
    Crowding distance sorting
    Tournament selection(generate next population P_{i+1} from R_i)
    Next generation Q_{i+1}
    i ← i + 1
```

B. Improved NSGA-II for Text Summarization

The improvements on NSGA-II are done in the context of keeping the length limit constraint and conforming to the constraint while each step is carried out. The improved version can also be generalized and applied to any genetic algorithm with initialization, mutation, or crossover. Since this is the case for every genetic-based algorithms, the method we suggest can be generalized to any genetic algorithm. As evolutionary algorithms generally do not consider the characteristics of each gene during the evolution progresses, each step generates infeasible candidate solutions which not only decreases the performance but also leads to inefficiency. In the text summarization task, the variance of the sentence lengths is quite high compared to the length constraint. For example, the DUC2002 competition had a summary length constraint of 200 words, and the sentence length varied from a couple of words up to 10% $\sim$ 20% of the length limit. We apply modifications in the initialization, crossover, and mutation part of the existing evolutionary multi-objective optimization algorithm to accommodate the 200 words limit constraint by adding or removing sentences from the summary. Algorithm 2 shows the process of proposed improved NSGA-II. The following explains the details of each step.

C. Chromosome Encoding

Each of the candidate summaries is considered as a chromosome since each sentence is encoded using one bit per sentence as explained in Section III. We use binary encoding for the summary representation.

Algorithm 3 Adaptive initialization

for each Entry in chromosome **do**
  for each gene g_i **do**
    Take a random real value γ between 0 and 1
    Take a random integer value σ between α and β
    if $\gamma < 1 - \frac{\sigma}{n}$ **then**
      $g_i \leftarrow 1$
    else
      $g_i \leftarrow 0$

1) Adaptive Initialization: We parameterize initialization with lower bound length variable α and upper bound length variable β. This process generates a random length chromosome approximately between α and β. Since one of the rationales behind the evolutionary algorithm to find optimal value is randomness, the proposed methods also reflect randomness throughout the process.

Algorithm 4 Adaptive mutation

INPUT: Mutation probability P_m, zeros ratio α, ones ratio β
for each gene in chromosome **do**
  Take a random real value γ between 0 to 1
  if $\gamma < p$ **then**
    Take a random real value γ' between 0 to 1
    if g_i is 0 **then**
      if $\frac{\bar{\gamma}}{2} < \alpha$ **then**
        $g_i \leftarrow 1$
    else
      if $\frac{\bar{\gamma}}{2} < \beta$ **then**
        $g_i \leftarrow 0$

2) Adaptive Mutation: A mutation operator ensures diversity in the population members. It is possible that crossover can not create new solutions. In this case, the mutation is used to perturb the solution and introduce new members to the population. The limitation of random mutation is that it has an adverse effect when the expected solutions are highly skewed. In the DUC2002 dataset, for example, the number of genes(sentences) in a chromosome range from 111 to 614 with an average of 260. Out of this chromosome length, only about 10 genes are to be selected in a candidate solution. Applying unskewed randomness leads to random gene selections, where more genes would be selected than necessary. Although the whole optimization process prevents the infeasible solutions, the power of each generation would be wasted because of the infeasible genes. Our strategy is to not allowing too much divergence from the initial ratio of selected and non-selected genes. We also randomize this process so that as the evolution progresses, some of the genes diverge from the initial ratio.

3) Adaptive Crossover: The crossover operator is responsible for choosing two random members and create two new child solutions. The parent and child solutions can be the same or different.

However, a desired skewness in the solution could become an issue as in initialization and mutation operation during the crossover stage. During a crossover, two chromosomes' subsequences between crossover location parameter s and t are swapped. Because of the initial gene skewness in the original chromosomes, this could lead to an undesirable degree of gene ratio altercation resulting in infeasible child solutions. To overcome this problem, we allow the exchange of the genes in a unit of pair. The selected pair exchange ensures that the number of active genes is maintained after the crossover.

Algorithm 5 Adaptive crossover.

INPUT: crossover probability P_c
Take random real number r between 0 and 1
for each Entry in chromosome **do**
  if $r \leq P_c$ **then**
    Select random integer i
    while x_i is y_i **do**
      Select random integer j
      while x_j is y_j **do**
        Crossover (x_i, y_i)
        Crossover (x_j, y_j)

D. Selection

The selection operator is used to select the better members within the population. Usually, two members are chosen randomly and the best one is chosen. Thereafter, multiple copies of the best solution members could be selected redundantly.

E. Stopping Criterion

The optimum number of generations is correlated with the number of sentences in the document collection. The stopping criterion could be given as the number of consecutive generations with static objective function outcomes. This method allows a different amount of evolution done to each of the topics, therefore we employed a previously utilized constant total generation number as the stopping criterion instead. This allows a more consistent comparison between the outcomes with a fixed number of evolution for all topics.

F. Constraint Handling

The DUC2002 MDS task requires a summary to include 200 words and the DUC2004 MDS task limits the summary to have 665 bytes. However, since the binary encoded candidates can be of any length, the summary can not exactly meet the constraint. This brings difficulty in measuring coverage and diversity. Therefore,we relax the 200 length constraint to allow a limit of $limit + maximumsentencelength - 1$. This allows us to fill in as much of the sentence as possible right before the limitation. For a fair comparison, we deduct the ROUGE score of our methods when comparing with the ones that followed strict constraints. The reduced ROUGE score for our method is as follows:

$$ROUGE_{reduced} = ROUGE * (1 - \frac{overflow}{limit}) \quad (9)$$

This metric reduces the ROUGE score as if the overflow part were not included in the evaluation.

TABLE III. THE DUC DATASETS

Description	DUC2002	DUC2004
Number of Topics	59	50
Number of Documents in each Topic	5∼15	9∼11
Number of Documents in Total	567	503
Data source	TREC	TDT
Summary length	200 terms	665 bytes

TABLE IV. STATISTICS OF THE DUC2002 DATASET

	Doc.	Sent.	Term(Unique)	Preprocessed Term(Unique)
average	9.6	260.0	5401.7(1844.7)	2931.6(1124.4)
max	15.0	614.0	11815.0(3387.0)	6134.0(1936.0)
min	5.0	111.0	2027.0(915.0)	1066.0(561.0)

G. Solution Selection Strategy

However we need to select one summary to compare with other existing methods, and multiple non-dominated solutions are given as a result of multi-objective optimization. Thus, we need a method to select one summary from the candidates. Here, we suggest a solution selection method for multi-objective optimization among the Pareto optimal solutions. As defined in III, the objective functions take the average of the similarities. This implies that the coverage function does not consider the number of sentences included in the candidate summary. We define the solution ranking equation using the sentence length and the coverage value. The strategy is flexible since the solution selection is not done at a certain generation, but is done per topic basis. Final solution for the topic τ is defined as follows:

$$Solution(C_\tau) = \underset{c \in C_\tau}{\operatorname{argmax}} f_{coverage_k}(c) \cdot l(c) \tag{10}$$

where C is the candidate summary set over all the generations on topic τ, $l(c)$ is the number of terms in the candidate summary c.

VI. EVALUATION

A. Dataset

The experiments are performed using the DUC datasets in the years 2002 and 2004. The DUC2002 dataset contains 59 topics with 5 to 10 documents included in each topic. The task is to generate a summary with a maximum of 200 words. The DUC2004 dataset contains 50 topics with 10 to 11 documents included in each topic. The goal for the DUC2004 MDS task is to generate a summary with a maximum of 665 bytes. Table III shows the statistics of the DUC2002 and DUC2004 datasets. Table IV and Table V show specific statics of the two dataset. The preprocessed terms are acquired by removing stopwords and stemming the words.

B. Metric

Recall-Oriented Understudy for Gisting Evaluation (ROUGE) metric is used by DUC for text summarization competition. ROUGE metric is used to compare experimental results against the gold standard summaries generated by human annotators. The ROUGE score measures how much the words in the human reference summaries overlap with the machine-generated summaries in terms of the n-gram by counting overlapping words or a word sequence. There are four types of ROUGE scores. ROUGE-N, ROUGE-L, ROUGE-W, ROUGE-S. We use 3 of these measures for our evaluation and comparison with other methods. As for ROUGE-S, we use ROUGE-SU, which is its variation. In this research, ROUGE-1, ROUGE-2, and ROUGE-S(ROUGE-SU) are used for the comparison. ROUGE-N is the most basic method of comparison. It measures N-gram co-occurrence statistics. ROUGE-N is computed as follows:

TABLE V. STATISTICS OF THE DUC2004 DATASET

	Doc.	Sent.	term(unique)	Preprocessed Terms(Unique)
average	10.1	259.4	5342.6(1899.9)	2811.3(1144.3)
max	11.0	531.0	9502.0(3111.0)	4990.0(1940.0)
min	9.0	81.0	2174.0(859.0)	1255.0(526.0)

$$ROUGE - N = \frac{\sum_{S \in sum_{ref}} \sum_{gram_N \in S} Count_m(gram_N)}{\sum_{S \in sum_{ref}} \sum_{gram_N \in S} Count(gram_N)} \tag{11}$$

where N is the length of the consecutive words used as a unit for the comparison. $Count_m(gram_N)$ is the maximum number of N-grams co-occurring in a candidate summary and the set of reference summaries. $Count(gram_N)$ is the total number of N-grams in the reference summarizes.

ROUGE-L is based on the longest common subsequence(LCS) metric. Here a summary sentence is viewed as a sequence of words. The rationale behind ROUGE-L is that the longer the LCS between the two summary sentences is, the more similar they are. We compare the union LCS matches between a reference summary sentence, r_i, and every candidate summary sentence, c_j.

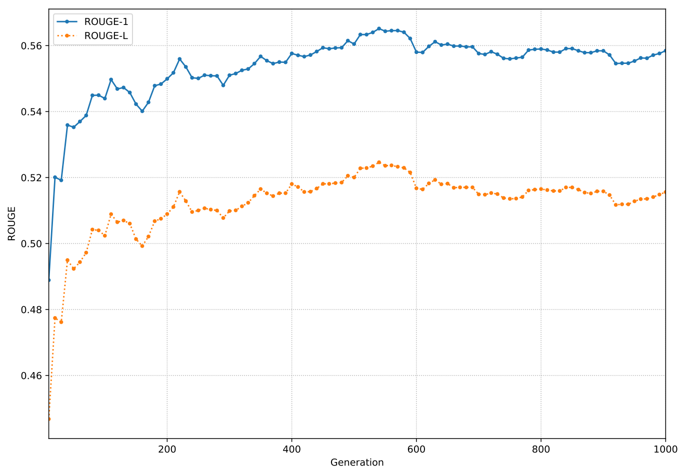
$u = [t_1, t_2, ..., t_m]$ and $v = [t_1, t_2, ..., t_n]$. $z = u \cup v$ with length θ. Let $LCS_{sequence}(x, y) = [t_1, t_2, ..., t_\theta]$ be the LCS word sequence representation between sentence u and sentence v. Given the sentence level LCS $R_{LCS}(R, S)$, reference summary of u sentences containing a total of m words and a candidate summary of v sentences containing a total of n words, ROUGE-L is computed as:

$$R_{LCS}(R, C) = \frac{\sum_{i=1}^{u} LCS_\cup(r_i, C)}{|R|} \tag{12}$$

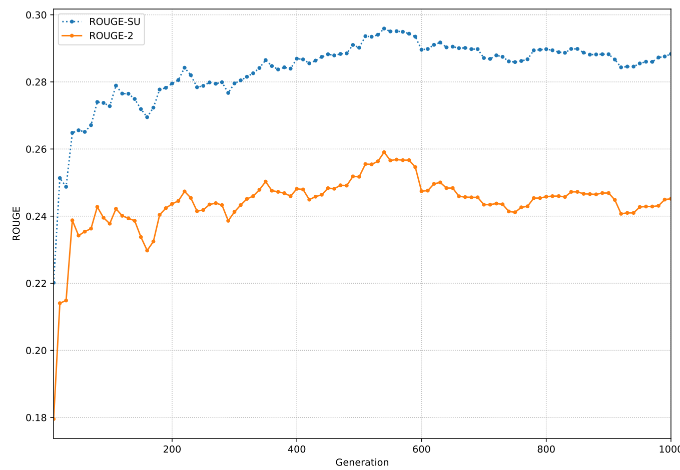
ROUGE-S is a skip-bigram co-occurrence measure. It counts ordered bigrams allowing for arbitrary gaps. ROUGE-SN is used to parameterize maximum skip distance.

$$R_{skip2} = \frac{SKIP2(R, S)}{C(|S|, 2)} \tag{13}$$

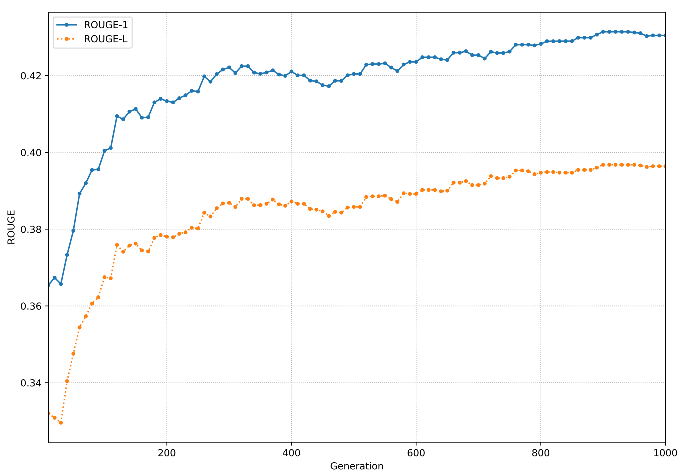
where SKIP2(R, S) is the number of skip-bigrams that match between the reference summary R and the candidate summary S. ROUGE-S shows poor evaluation result if the skip-grams are not detected. So when the two sentences consist of the same words but with reversed order, ROUGE-S will assign 0 value to the pair. To overcome this potential problem, ROUGE-SU, an extension of ROUGE-S is used in our experiment. ROUGE-SU extends ROUGE-S by adding unigram as a counting unit in addition to ROUGE-S.



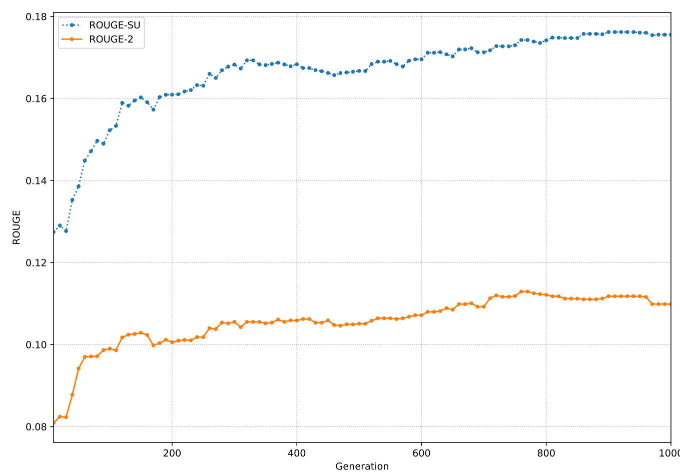
(a) **DUC2002**: ROUGE-1 & ROUGE-L over generations.



(b) **DUC2002**: ROUGE-2 & ROUGE-SU over generations.



(c) **DUC2004**: ROUGE-1 & ROUGE-L over generations.



(d) **DUC2004**: ROUGE-2 & ROUGE-SU over generations.

Fig. 1. Various ROUGE Scores over Generations of Evaluation on the DUC2002 & DUC2004 Datasets

Summarization approaches with non-optimization methods use ROUGE-1, ROUGE-2, ROUGE-L, ROUGE-SU for their evaluation. The ones with optimization methods use ROUGE-2 and ROUGE-L for their evaluation. For the comparison with the two groups, we adopt the list of metrics respectively. The meaning of each metric is quite important. ROUGE-L reflects the most important sequence therefore is more focused on the main contents when comparing the sentences. ROUGE-2 will count every bigram units, which may suffer from unimportant bigrams being a source of an inaccurate comparison.

VII. Result

A. Experiment Setup

The population is set to 50, and generation is set to 1000 for the existing methods as other evolutionary methods [9], [6], [4] did. The population is changed to 52 for the proposed method as NSGA-II contains a tournament selection stage where the population should be set to a multiple of four. This does not give advantage to our method, since as you can see in Fig. 1. The local optimum reaches before 1000$^{\text{th}}$ generation, and we apply our solution selection method described in Section V much earlier than the initially defined condition. Mutation probability is set to $5 \cdot \frac{1}{n_i}$ where n_i is number of sentence in topic i. Crossover probability is set to 0.8. Our initialization is done with a random number of sentences between 7 to 11.

TABLE VI. ROUGE-2 Comparison with Evolutionary Optimization Methods on the DUC2002 Dataset

Topic	GO[4]	ABCO[6]	**KE-B**	**KE-K**	**KE-B***	**KE-K***
d061j	0.305	0.365	0.377	0.343	0.427	0.343
d062j	0.200	0.342	0.100	0.115	0.105	0.188
d063j	0.275	0.272	0.257	0.276	0.307	0.276
d064j	0.233	0.308	0.339	0.469	0.339	0.469
d065j	0.182	0.198	0.149	0.104	0.333	0.270
d066j	0.181	0.290	0.263	0.234	0.263	0.234
d067f	0.260	0.356	0.217	0.345	0.330	0.394
d068f	0.496	0.444	0.393	0.360	0.521	0.479
d069f	0.232	0.240	0.147	0.168	0.406	0.178
d070f	0.262	0.305	0.241	0.380	0.245	0.388
Avg	**0.263**	**0.312**	**0.253**	**0.279**	**0.328**	**0.325**

TABLE VII. ROUGE-L COMPARISON WITH EVOLUTIONARY OPTIMIZATION METHODS ON THE DUC2002 DATASET

Topic	GO[4]	ABCO[6]	**KE-B**	**KE-K**	**KE-B***	**KE-K***
d061j	0.554	0.590	0.590	0.595	0.629	0.595
d062j	0.481	0.536	0.438	0.448	0.453	0.464
d063j	0.528	0.509	0.550	0.530	0.550	0.530
d064j	0.488	0.495	0.575	0.663	0.579	0.663
d065j	0.457	0.464	0.439	0.439	0.534	0.511
d066j	0.441	0.519	0.558	0.510	0.558	0.524
d067f	0.529	0.580	0.475	0.588	0.559	0.632
d068f	0.626	0.639	0.632	0.646	0.736	0.698
d069f	0.476	0.554	0.510	0.561	0.672	0.571
d070f	0.513	0.515	0.466	0.563	0.479	0.563
Avg	**0.509**	**0.540**	**0.523**	**0.554**	**0.575**	**0.575**

TABLE VIII. ROUGE SCORES FROM THE DUC2002 DATASET

Methods	ROUGE-1	ROUGE-2	ROUGE-L	ROUGE-SU
KNET-EMO-K*	0.5680	0.2921	0.5328	0.3079
KNET-EMO-B*	0.5612	0.2853	0.5264	0.3020
KNET-EMO-K	0.5385	0.2409	0.4978	0.2810
KNET-EMO-B	0.5284	0.2295	0.4854	0.2731
WFS	0.4994	0.2582	0.4893	0.2874
OCDsum-SaDE	0.4990	0.2548	0.4708	0.2855
DUC	0.4987	0.2523	0.4680	0.2841
MCKP	0.4938	0.2511	0.4694	0.2855
WCS	0.4933	0.2484	0.4628	0.2789
BSTM	0.4881	0.2457	0.4552	0.2702
FGB	0.4851	0.2410	0.4508	0.2686
LexRank	0.4796	0.2295	0.4433	0.2620
Centroid	0.4538	0.1918	0.4324	0.2363
NMF	0.4459	0.1628	0.4151	0.2169
LSA	0.4308	0.1502	0.4051	0.2023
Random	0.3878	0.1196	0.3771	0.1852
CRSum-SF	0.3890	0.1028	·	·

We compare the proposed model with two different groups of methods. One group of methods is the ones that can be compared using the DUC2002 and DUC2004 datasets and the other group is the ones with evolutionary optimization algorithms where only topics from 61 to 70 in the DUC2002 dataset are considered in the literature [6], [37]. Each of the methods for the comparison is shown in Table I. Some of the methods are taken from the list in Alguliev et. al. [9], and we extend the list with other methods not listed in the paper.

B. Evolutionary Multi-objective Optimization Results

We first verify whether the multi-objective optimization formulation of the summarization problem is valid. Fig. 1 shows the ROUGE results over generations. We can observe that the proposed algorithm generally produces an improved result as the generation passes. Note that the improvement is not a monotonic increase. Before reaching generation 200, all four graphs show a valley, a decrease of ROUGE score compared to the previous generations. One of the reasons for this phenomenon is that there is a length limitation. To find a solution that maximizes the objective function, the genes are continuously changed through mutation and crossover. Since the objective functions are defined to consider the average similarity of the sentences in a candidate solution, certain generations may contain the ones with a smaller number of sentences which may be given a low ROUGE score as the summary does not fully utilize the 200 word limit. Considering a little fluctuation as an inevitable variance throughout the evolution process, we can see the evolutions are generally improving towards higher ROUGE scores.

TABLE IX. ROUGE SCORES FROM THE DUC2004 DATASET

Methods	ROUGE-1	ROUGE-2	ROUGE-L	ROUGE-SU
KNET-EMO-K*	0.4281	0.1250	0.3967	0.1891
KNET-EMO-K	0.4094	0.1105	0.3760	0.1746
KNET-EMO-B*	0.4080	0.1046	0.3786	0.1662
KNET-EMO-B	0.3958	0.0985	0.3643	0.1626
WFS	0.3933	0.1121	0.3960	0.1354
OCDsum-SaDE	0.3954	0.0969	0.3927	0.1367
CRSum-SF	0.3953	0.1060	·	·
DUCbest	0.3822	0.0922	0.3869	0.1323
MCKP	0.3864	0.0924	0.3892	0.1333
WCS	0.3987	0.0961	0.3893	0.1353
BSTM	0.3907	0.0901	0.3880	0.1322
FGB	0.3872	0.0812	0.3842	0.1296
LexRank	0.3784	0.0857	0.3753	0.1310
Centroid	0.3673	0.0738	0.3618	0.1251
NMF	0.3675	0.0726	0.3675	0.1292
LSA	0.3415	0.0654	0.3497	0.1195
Random	0.3227	0.0639	0.3488	0.1197

Another characteristic to discuss in Fig. 1 is that for the DUC2002 dataset, the peak is reached quite faster than the results of the DUC2004 dataset. Our further experiment using 200 populations and 2000 generations showed that the performance improves as the generation continues. The graphs resemble a fractal structure, where the local pattern is similar to the global pattern. But since we need to find the best solution among the candidate solutions, we propose a solution selection strategy to select solutions from various generations for each topic as explained in Section V.

C. Comparison with Multi-objective Methods

Table VI and Table VII show the ROUGE score comparison between the proposed Knowledge-based Named Entity Topic Construction using Evolutionary Multi-objective Optimization(KNET-EMO, shown as KE in tables) and its variations along with two existing multi-objective optimization methods. KNET-EMO-B(KE-B) is the base method without using the knowledge-based topic construction approach and only using the improved NSGA-II. KNET-EMO-K(KE-K) is the proposed method that reflects all of our main contributions. (*) are the ROUGE scores of the solutions manually selected for their summarization qualities, showing that the multi-objective optimization has successfully generated high performing results.

From the average scores in Table VI and Table VII, ROUGE-L shows superior performance compared to ROUGE-2. This implies the proposed method successfully found the sentences that contain the core contents of the original documents in a more relaxed manner. Low ROUGE-2 and high ROUGE-L suggest that it is robust when we need to generate summaries from the real-world text. This is because it can generate the summaries regardless of the exact sequence of the terms while allowing other terms to appear in between, which is a more human way of selecting the sentences.

A high ROUGE-2 score can be manually achieved by taking the sentences from the answer set and select the ones from them because this will lead to the same sequence which leads to high ROUGE-2. But high ROUGE-L cannot be generated in this manner. This can be only achieved by selecting the sentences that reflect the original document, but not the same sequence of terms in the answer set. The generally observed pattern of high ROUGE-2 and low ROUGE-L scores in other research is more adapted or even overfitted to the given task alone. The proposed method showed the opposite result, indicating it can be generalized to other text corpora, unlike the existing methods.

Another factor for this result is the difference in the sentence parsing method. If the sentence parsing is more consistent with human judgment, it will not have a negative influence on the performance. But if the sentence parsing is not synchronous with human judgment it can have a negative influence on the bigram measure.

The best scores, KNET-EMO-B*(the base method) and KNET-EMO-K*(the knowledge-based method) are both 0.575 from Table VII, but the solution selected scores KNET-EMO-B and KNET-EMO-K differ. We can understand it as a knowledge-based coverage measure combined with our solution selection method is more suitable in finding the solutions regarding human judgment.

D. Comparison with General Methods

Table VIII and Table IX show the comparison to the generally known text summarization methods. We compare the results using ROUGE-1, ROUGE-2, ROUGE-L, and ROUGE-SU as previously explained. Since we compare against evolutionary algorithms, we defined the tolerance threshold and used the value for the summary length limit as in other evolutionary optimization methods. This is to avoid cutting off the sentence at the limit point but include the ones when the constraint limit is violated. Otherwise, we cannot fill the content within the length limit. Here for the comparison with the general methods, we normalize our results with the ratio between the limit and the tolerance threshold. This is to deduct the ROUGE score that the proposed method may have gained by having the tolerance threshold.

According to the tolerance threshold defined in Section V, the average of the maximum length sentences from each topic is 49 bytes for the DUC2002 and 57.78 bytes for the DUC2004. For DUC2002 we need to convert these 49 bytes into the word count. Since the average word length of the DUC2002 corpus is 5.5 and we need to add a 1 byte for a space for each word, the average word tolerance for the DUC2002 dataset is $\frac{49}{6.5} = 7.54$. This means that our method accepted the candidate summaries that do not violate more than or equal to the average of 7.54 words for the DUC2002 datasets and 57.78 bytes for the DUC2004 datasets. For a fair comparison, we assume that the solutions in the proposed method fully utilize this advantage and normalize it with the ratio of the tolerance from the total length. So for DUC2002, $\frac{49}{200} = 3.8\%$ is deducted from the ROUGE score of our method. For DUC2004, 57.78/665 = 8.7% is deducted from the ROUGE score of our method. So we compete using 96.2% of the ROUGE scores from the proposed method for the DUC2002 dataset against the methods listed in the result Table VIII, and 91.3% of the ROUGE scores from the proposed method for the DUC2004 dataset against the other methods in result Table IX.

Table VIII and Table IX both shows that the proposed method outperforms existing methods on both the DUC2002 and DUC2004 datasets. The values in the (*) is the score of the manually selected best solution from the candidate summary pool. They show that although our selection method can find nice solutions, they are not the best among the candidate solutions found from the evolution. This confirms that our problem formulation of text summarization as a multi-objective optimization is validated as the candidates contain solutions with very high scores. Note that KNET-EMO-K outperforms the best candidate(KNET-EMO-B*) using the base method. This confirms that the proposed knowledge-based named entity topic construction method outperforms the base method using only the evolutionary multi-objective optimization.

We have observed from the experiment results that after reaching the ROUGE performance peak, as the evolution continues, the ROUGE score decreases after certain generations as explained previously. The objective function is an approximation of the ideal objective as human summarizers use heuristics to generate summaries. Although human summarizers aim to generate summaries that are to a certain extent optimized, it needs not to be as optimal as the result of the automatic summarizers. Thus, finding an optimal stopping point is one of the future research topics to work on.

VIII. CONCLUSION

In this research, the authors proposed a multi-objective optimization approach for the automatic text summarization. On top of the framework based on an evolutionary multi-objective optimization, a novel method to utilize a knowledge base is proposed. Combining knowledge base utilization method and the improvement algorithm on the evolutionary multi-objective optimization steps, the evaluation results have shown that the proposed method not only out-performs previous research on text summarization but also shows better performance compared to the recent research on evolutionary multi-objective optimization techniques. For future works, many-objective optimization formulation of the text summarization is considered where the framework can take more objective functions to pursue more precise optimization. As discussed previously, there are further research opportunities with regards to early stopping method so that we can find the level of optimization the human summarizers achieve. Finally, an extension of the knowledge base methods are to be studied for a better solution selection method given multiple Pareto optimal candidate solutions.

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An Adaptive Discrete Brain Storm Algorithm Solves 3D Protein Structure Prediction

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***Abstract*—Brain Storm Optimization (BSO) is one of the major effective swarm intelligence algorithms that simulate the human brainstorming process to find optimality for optimization problems. BSO method has successfully been applied to many real-world problems. This study employs BSO method, called BSO-IP, to solve the integer programming problem. Our method collects best solutions to generate new solutions that then search for optimal solutions in all areas of search space.The BSO-IP method solves some benchmark integer programming problems to test its efficiency. The BSO-IP is used to simulate the 3D protein structure prediction problem, which is mathematically presented as an integer programming problem to approve the viability and helpfulness of our proposed Algorithm. The experimental results of different benchmarks protein structure show that our proposed method is superior in high performance, convergence, and stability in predicting protein structure. We examined our strategy results to be promising compared to other results.**

***Keywords*—Brain storm optimization; integer programming problem; three dimensional protein structure prediction**

I. Introduction

The optimization problem is a significant branch of modern science problem. Previously, Scientists took more time to find an optimal solution to these problems. However, recently, widely researched Optimization problems depend on the population. The algorithms for this subject are called population-based optimization algorithm. The population- based optimization problem works by communicating and competing with each other, and its optimization algorithms are classified as swarm intelligence algorithms.

Particle swarm optimization (PSO) [1], bacterial foraging optimization [2] , artificial bee colony optimization [3], and ant colony optimization (ACO) [4] are examples of PSO are inspired by animals and insects such as ants, birds, and bees. Brain Storm Optimization (BSO) is a new type of PSO, proposed by Shi [5, 6]. Many researchers play significant efforts to develop the BSO algorithm to make it more efficient.

BSO depends on two major functions, namely, divergence and convergence. Learning and developing capabilities are the two basic functions that BSO possesses. Divergence correlates with learning and convergence with developing capabilities. These functions find better possible solutions than the current solution, which depends on one member of the population. These two functions are essential to finding the best potential solutions to solve (NP) problems. The BSO algorithm is a mixture of swarm intelligence and data mining techniques. Each solution produced using the BSO algorithm not only solves the problem but is also an outlet to other solutions to the problem. This feature is the sole characteristic of combining swarm intelligence and data mining techniques.

Most of BSO algorithms are employed to solve the continuous optimization problem [7] and [8]. Only a few papers have been dedicated integer programming problems and their real applications like [9]. This study employs the BSO algorithm ,called the BSO-IP, to solve an integer programming problem, to solve some benchmark integer programming problems, Also, BSO-IP results were compared with those from other methods to show our method strength. The BSO-IP method makes an adaptive update to solutions by collects the best solutions to help to generate new solutions that differentiate them to search for optimal solutions in all areas of the search space.

This paper presents the BSO Algorithm approach to one of the most important problems in bioinformatics, which is the protein structure prediction (PSP) in 3D. PSP is characterized by forecasting of the 3D structure of a protein using its essential structure data. PSP is a significant research topic in bioinformatics, medication, and different fields such as sedate structure, and the forecast of maladies. The dimensional folding structure of a protein determines its biological function. There are many traditional experimental methods to determine protein folding structure such as X-ray crystallography and NMR spectroscopy [10].

PSP is presented as a mathematical form, which is an integer programming. BSO-HP algorithm, simulated to solve different benchmarks benchmarks HP model. is used to test the effectiveness of the BSo-HP algorithm.

However, they are very expensive and time-consuming because of the polypeptide chain structures such enormous number of various spatial structures. It is as yet difficult to look for the global minimum energy conformations of proteins from its sequence of amino acids and make analysis for the protein folding process. The most series problem lies in finding the simplest model representing the relationship between the structure of a protein and free energy.

Whatever is left of the paper is sorted out as taken after. In Section II, we highlight the fundamental techniques and structure for the BSO method and briefly review of the integer programming problem. The design of the proposed methods for the integer programming problem known as BSO-IP is introduced, and the numerical experiments of the BSO-IP method are discussed in Section III. The BSO method is applied to solve PSP as HP- BSO strategy in Section IV. Furthermore the correlation between the proposed technique and different strategies in Section V, Finally, Section VI shows the conclusions of this paper.

II. Related Work

A. Brain Storm Optimization Method Techniques

The BSO algorithm was designed by Shi [5, 6] like other swarm intelligence optimization algorithm but inspired by the brain of the human brain processing. Humans are the smartest living creatures ever,so algorithms based on humans and on human behavior are more effective and rewarding than those from insects, ants, and other living things.

The BSO algorithm is designed according to the brain-storming process. Osborn created four rules to generate the idea. Open-minded people generate many different ideas during brainstorming. Every population in the BSO algorithm contains a group of diverse ideas. At the end of every step of brainstorming, Every population in the BSO algorithm contain a group of diverse ideas. At the end of every step of brainstorming , every idea will be evaluated. Therefore, no idea ignored.

There are five major operations of the BSO algorithm are shown in Fig. 1 with the following description:

- Population initialization.
- Evaluating individuals.
- Clustering individuals.
- Disrupting cluster centers.
- Updating individuals.

In initialization, populations are generated randomly from the normal distribution inside the search space, and the size of the population is constant at every iteration. It is necessary to evaluate each individual after each generation because evaluated value determines the competence of the individual as the potential solution. Many of clustering types can be used in the clustering step however, the K-means clustering algorithm is applied in the BSO algorithm. The updating individual step includes two suboperation presented in the following equations:

$$\begin{aligned} x^i_{new} &= x^i_{old} + \zeta(t) + random(t) \\ x^i_{old} &= \omega 1 * x^i_{old1} + \omega 2 * x^i_{old2} \end{aligned} \tag{1}$$

Where x^i_{old} is the summation of i-dimensional of x^i_{old1} and x^i_{old2} weights, and ω_1 *and* ω_2 are coefficients for weighting two existing individuals. ω_1 and ω_2 2 equal 0 if new individual x^i_{new} is generated depending on existing individual x^i_{old}. And if it depends on two existing individuals $x^i_{old1}$and x^i_{old2} , then the coefficient ζ(t) is randomly generated by one possibly function:

$$\zeta(t) = \log sig \left| \frac{\frac{T}{2} - t}{k} \right| * random(t) \tag{2}$$

where logsig() is a logarithmic sigmoid transfer function, T is the maximum number of iterations, t is the current iteration number, k is the chang in slope of the logsig(), and random() is a random value within (0,1).

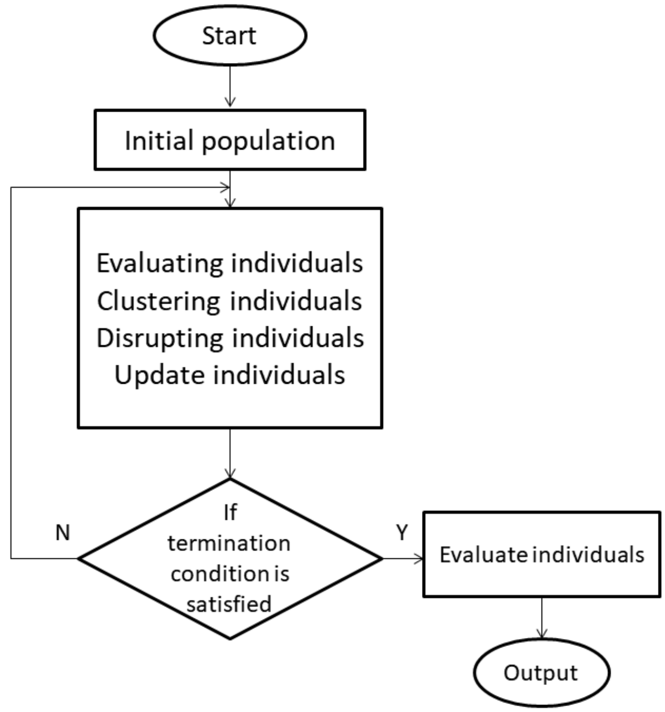


Fig. 1. BrainStorm Optimization Flowchart.

B. Integer Programming Problem

An integer programming problem, as an optimization problem in mathematical form, contains a few or the entirety of the variables confined to be integers. The mathematical programming problem can be represented in a mathematical form as follows:

$$\begin{aligned} \min \quad & f(\mathbf{y}), \\ s.t. \quad & g_i(\mathbf{y}) < 0, \quad i = 1, \ldots, I, \\ & h_j(\mathbf{y}) = 0, \quad j = 1, \ldots, J, \\ & \mathcal{L}_l \le y_l \le \mathcal{U}_l, \quad l = 1, \ldots, n, \end{aligned} \tag{3}$$

where f, g, h are nonconvex functions in the general case, and n is the number of discrete variables. $\mathcal{L}_\mathbf{y} = (\mathcal{L}_1, \ldots, \mathcal{L}_n)$, and $\mathcal{U}_\mathbf{y} = (\mathcal{U}_1, \ldots, \mathcal{U}_n)$, are thelower and upper bounds for discrete variables, respectively. Problem (3) is the same as general nonlinear programming except that the design variables can take on any form of zero-one, integer and discrete variables. Therefore, the penalty methodology [11] was employed to transform this constrained problem into series of unconstrained problems, whose unconstrained solutions converge to the solutions of the constrained problem.

1) *Penalty Function:*

The penalty method transforms a constrained optimization problem by a series of unconstrained problems whose solutions must converge to the solution of the original constrained problem. In the case of minimization with inequality constraints, the corresponding minimization problems are formed by adding a penalty term to the objective function. The penalty term grows when the constraints are violated and is set to zero in the region where constraints are not violated. The penalty term is usually a product of a positive

penalty coefficient and a penalty function.
We try to solve the constrained Equation (3), where f , g_i and h_i are real valued function defined in search space, $S \subset R^n$ The general formulation of the exterior penalty function is:

$$\varphi(y) \;-f(y) \pm [\sum_{i=1}^{I} \; r_i + G_i + \sum_{j=1}^{j} \; c_j \;\; \times L_j] \tag{4}$$

Where $\varphi(y)$ is the new objective, G_i and L_i are called constraint violation function, and most common form is for them are

$$\begin{aligned} G_i &= max[0, g_i(y)]^\alpha \\ L_j &= [h_j(y)]^\beta \end{aligned} \tag{5}$$

Where $\alpha \; and \; \beta$ are normally 1 or 2. There are many different formulations of penalty function.

III. An Adaptive Discrete Brain Storm Optimization Algorithm for Integer Programming Problem

A discrete BSO method is simulated to solve integer programming problem as NP problem, which is called BSO-IP. The key operations of the BSO-IP algorithm are designed as the following description.

A. Initial Population

Initial population p was created from the uniform random distribution inside the search space. The population size pop_num is a fixed around all search processes.

B. Clustering Individuals and Disrupting Cluster Centers

Clustering analysis is considered unsupervised learning. It is a technique to divide data into several groups. The m goal of clustering algorithms is to separate data into small groups with similar and related objects. There are two ways of measuring similarity in the clustering analysis: first, finding an intercept between objects. In another way, the distance between the objects is calculated or measured; second, calculating distance is the common way to measure the similarity in clustering. The clustering process is similar to the brainstorming process of dividing ideas into small groups with similar objects. We applied the K-mean clustering algorithm [12] because its efficiency and accurate computation. Procedures 3.1 demonstrates the clustering technique.

Procedure 3.1: Clustering Technique
1. Let X = $x_1, x_2, \ldots, x_n$ be the set of data points and V = $v_1, v_2, \ldots, v_c$ be the set of centers.
2. Randomly select 'c' cluster centers
3. Calculate the distance between each data point and cluster centers using k-mean algorithm.
4. Assign the data point to the cluster center whose distance from the cluster center is the minimum of all cluster centers.
5. Recalculate the new cluster center using: where, 'c_i' represents the number of data points in the ith cluster.
6.Recalculate the distance between each data point and newly obtained cluster centers using the k-mean algorithm.
7. If no data point was reassigned then stop, otherwise repeat from Step 3.

C. Updating Individuals

1) New Individual Generation: To generate new individuals, we employ the prior information the best individuals saved in *Best-list*. The best individuals are generated after generating the initial population.

A new individual is generating based on one or two clustering centers with the following details:

- One Individual Mutation
  Procedure 3.2: One Individual Mutation
  1. Select one clustering center randomly P_C.
  2. Generate r_mutate as a random number in $[0, 1]$
  3. If $r_mutate < 0.6$ do Step 4, otherwise do Step 5.
  4. Select any gene in P_C and change its value from the individual in *Best-list*.
  5. Select two genes in P_C and change their values from the individual in *Best-list*.

- Two Individuals Operators
  Procedure 3.3: two Individuals operators
  1. Select two clustering centers randomly P_{C1} and P_{C2}.
  2. Determine the similar part in P_{C1} with the best individuals in *Best-list*.
  3. Change the selected part in P_{C1} with the corresponding part in P_{C2}.

2) Selection: When executing the algorithm, the population size does not change; rather, it is fixed. In each iteration, a new individual is replaced with the old individual. The replacement follows the selection technique: preserving the best by comparing the new individual to the old individual in the same index and choosing the best. Finally, the *Best-list* is updated with the enhancement individuals.

The BSO-IP algorithm criteria are presented in Fig. 2.

1. Randomly generate n potential solutions (individuals)
2. Evaluate the n individuals.
3. Cluster n individuals into m clusters.
4. Rank individuals in each cluster and record the best individual as its cluster center in each cluster.
5. Randomly generate a value r_replace in the range [0, 1)
6. if the value is smaller than a probability p_repalce then:
   - Randomly select a cluster center.
   - Randomly generate an individual to replace the selected cluster center.
7. For i=1 to N(Population Size);
8. Generate a random value r_one in the range [0, 1);
9. If is smaller than a probability p_one then:
   - Generate a random value r_one_center in the range [0, 1);
   - If is smaller than a probability p_one_center then:
     - Select the cluster center and add random values to it to generate new individual;
   - Else, Randomly select a normal individual from this cluster and add random value to the individual to generate new individual;
10. Else, Randomly select two clusters to generate new individual;
11. Generate a random value r_two_center in the range [0, 1);
12. If the value r_two_center is less than a probability then:
    - the two cluster centers are combined and then added with random values to generate new individual
13. Else, two normal individuals from each selected cluster are randomly selected to be combined and added with random values to generate new individual;
14. The newly generated individual is compared with the existing individual with the same individual index; the better one is kept and recorded as the new individual;

Fig. 2. Brain Storm Optimization Algorithm.

D. Numerical Experiment

The values of some parameters are set to the values reported in the literature. Other parameters are set with a preliminary numerical experiment. The values of parameters are presented in Table I.

TABLE I. BSO-IP PARAMETERS

Parameter Operator	Paramter Value	Description
cluster num	5	The number of k-means clusters
p_replace	0.4	The probability of replacing operator
p_one	0.4	The probability of selecting one cluster
p_one_center	0.3	The probability of selecting the center of one cluster
p_two_center	0.2	The probability of selecting The centers of two clusters

1) Results of Unconstrained Problems: The BSO-IP method is applied to solve eight unconstrained well-known problems which are showed in Table II.

TABLE II. UNCONSTRAINED FUNCTIONS

functions	Definition	Range	optimal solution
g_1	$\lvert y_1\rvert + \lvert y_2\rvert + \ldots + \lvert y_D\rvert$	$D = 5, 10, 15, 20, 25, 30$	0
g_2	$Y^T Y$	$D = 5$	0
g_3	$(9y_1^2 + 2y_2^2 - 11)^2 + (3y_1 + 4y_2^2 - 7)^2$	$D = 2$	0
g_4	$(y_1 + 10y_2)^2 + 5(y_3 - y_4)^2 + (y_2 - 2y_3)^4 + 10(y_1 - y_4)^4$	$D = 4$	0
g_5	$2y_1^2 + 3y_2^2 + 4y_1y_2 - 6y_1 - 3y_2$	$D = 2$	-6
g_6	$-3804.84 - 138.08y_1 - 232.92y_2 + 123.08y_1^2 + 203.64y_2^2 + 182.25y_1y_2$	$D = 2$	-3833.12
g_7	$(y_1 - 2)^4 + (y_1 - 2y_2)^2$	$D = 2$	0
g_8	$y_1^2 - 4y_1 - 2y_1y_2 + 2y_2^2$	$D = 2$	-8

g_1 has various dimensions n=5, 10, 15, 20, 25, 30. The problems from g_1 to g_6 are mentioned in [13],whereas g_7 and g_8 problems are mentioned in [14].The BSO-IP method is programmed in MATLAB and ran 50 times to get the results, which satisfy the termination condition of obtaining the optimal solution with errors 10^{-3} or to get the maximum number of iterations.

Table III presents results for the BSO-IP method. Also, g* is the known solution, g-best is the best solution obtained by the proposed method, g-mean is the mean of the optimal values, SR is the success rate, and g-evolution is the fitness function evolution.

TABLE III. BSO-IP METHOD FOR UNCONSTRAINED PROBLEMS

g	n	g*	g-best	g-mean	SR	g-evolution
1	5	0	0	0	100	114.4
1	10	0	0	0	100	113.8
1	15	0	0	0	100	114.8
1	20	0	0	0	100	112.5
1	25	0	0	0	100	117.4
1	30	0	0	0	100	118.6
2	5	0	0	0	100	112.4
3	2	0	0	0	100	77.62
4	4	0	0	0	100	114.26
5	2	-6	-6	-6	100	62.42
6	2	-3833.12	-3833.12	3833.12	100	135.2
7	2	0	0	0	100	113
8	2	8	8	8	100	2840

We compare the BSO-IP method with PSO-In, PSO-Co, PSO-BO, and BB methods [15]. The BSO-IP Algorithm ran 30 times under termination conditions to reach to the exact solution with accuracy 10^{-6} or got 2500 as presented in PSO-In, PSO-Co, PSO-BO, and BB methods in Table IV. Alternatively, Table V presents the comparison between our proposed method and PSO-In, PSO-Co, PSO-BO,and BB methods. The results show that the BSO-IP method found all the optimal solutions for the test problem with the lowest fitness function evolution.

TABLE IV. COMPARISON SHOWING EXACT SOLUTION WITH ACCURACY 10^{-6} IN PSO-IN, PSO-CO, PSO-BO, AND BB METHODS

g	n	Solver	g-eval	St.D	SR	g-best
g_1	5	**BSO-IP**	**111.9**	**10.55**	**100**	**0**
		PSO-In	1646	661.5	100	0
		PSO-Co	744	86	100	0
		PSO-Bo	962.6	97	100	0
		BB	1167.38	659.8	100	0
g_2	10	**BSO-IP**	**111.9**	**10.55**	**100**	**0**
		PSO-In	1646	661.5	100	0
		PSO-Co	744	86	100	0
		PSO-Bo	962.6	97	100	0
		BB	1167.38	659.8	100	0
g_3	15	**BSO-IP**	**111.9**	**10.55**	**100**	**0**
		PSO-In	1646	661.5	100	0
		PSO-Co	744	86	100	0
		PSO-Bo	962.6	97	100	0
		BB	1167.38	659.8	100	0
g_4	20	**BSO-IP**	**111.9**	**10.55**	**100**	**0**
		PSO-In	1646	661.5	100	0
		PSO-Co	744	86	100	0
		PSO-Bo	962.6	97	100	0
		BB	1167.38	659.8	100	0
g_5	25	**BSO-IP**	**111.9**	**10.55**	**100**	**0**
		PSO-In	1646	661.5	100	0
		PSO-Co	744	86	100	0
		PSO-Bo	962.6	97	100	0
		BB	1167.38	659.8	100	0
g_6	30	**BSO-IP**	**111.9**	**10.55**	**100**	**0**
		PSO-In	1646	661.5	100	0
		PSO-Co	744	86	100	0
		PSO-Bo	962.6	97	100	0
		BB	1167.38	659.8	100	0

TABLE V. COMPARISON BETWEEN THE BSO-IP METHOD WITH PSO-IN, PSO-CO, PSO-BO, AND BB METHODS

g	n	Solver	g-eval	St.D	SR	g-best
g_2	5	**BSO-IP**	**110.3**	**19.94**	**100**	**0**
		PSO-In	1655.6	618.4	100	0
		PSO-Co	428.0	57.9	100	0
		PSO-Bo	418	83.9	100	0
		BB	139.7	102.6	100	0
g_3	2	**BSO-IP**	**75.2**	**62.2**	**100**	**0**
		PSO-In	3.4.0	101.6	100	0
		PSO-Co	297.3	50.8	100	0
		PSO-Bo	302.0	80.5	100	0
		BB	316.9	125.4	100	0
g_4	4	**BSO-IP**	**116.3**	**12.96**	**100**	**0**
		PSO-In	1728.6	518.9	100	0
		PSO-Co	1100.6	229.2	100	0
		PSO-Bo	1082.0	295.6	100	0
		BB	2754.0	1030.1	100	0
g_5	2	**BSO-IP**	**54.6**	**35.25**	**100**	**-6**
		PSO-In	178.0	41.9	100	-6
		PSO-Co	198.6	59.2	100	-6
		PSO-Bo	191.0	65.9	100	-6
		BB	211.1	15.0	100	-6
g_6	2	**BSO-IP**	**126.73**	**164**	**100**	**-3833.12**
		PSO-In	334.6	95.5	100	-3833.12
		PSO-Co	324.0	78.5	100	-3833.12
		PSO-Bo	306.6	96.7	100	-3833.12
		BB	358.6	14.7	100	-3833.12

2) Results of Constrained Problems: BSO-IP method is applied to solve constrained problems. The performance of the BSO-IP method is presented on well-known problems f_1 to f_4, [16] shown in Table VI. Our proposed method solves constrained problem by transforming it into an unconstrained problem by using the penalty function equations 5 and 4:

The BSO-IP MATLAB code runs 50 times with the termination condition is to find the exact solution with an error of 10^{-6} or to get the maximum number of iterations. The result of our method is shown in Table VII.

TABLE VI. BENCHMARK CONSTRAINED FUNCTIONS

functions	Definition	Range	optimal solution
f_1	$y_1^2 + y_2^2 + y_3^2 + y_4^2 + y_5^2$	$D = 5$	8
f_2	$exp(-y_1) + {y_1}^2 - y_1y_2 - 3{y_2}^2 - 6y_2 + 4y_1$	$D = 2$	-42.632
f_3	${y_1}^2 + y_1 * y_2 + 2{y_2}^2 - 6y_1 - 2y_2 - 12y_3$	$D = 3$	-68
f_4	$(y_1 + 2y_2 + 3y_3 - y_4)(2y_1 + 5y_2 + 3y_3 - 6y_4)$	$D = 4$	-6

TABLE VII. BSO-IP METHOD FOR CONSTRAINED PROBLEM

f	n	f^*	f-best	f-mean	SR	f-eval
f_1	5	8	8	8	100	151.96
f_2	2	-42.632	-42.632	-42.632	100	24.2
f_3	4	-68	-68	-68	100	312.93
f_4	4	-6	-6	-6	100	99.7

Table VIII presents the comparison between BSO-IP methods with MI-LXPM, RST2ANU and AXNUM methods [16] for 4 well-known problems f_1 to f_4. The results follow after the BSO-IP code runs 50 times and the termination condition to reach the optimal solution with an error of 0.01 or achieve the maximum number of iterations. The termination condition is presented in [16] to compare our result with other methods with the same termination condition.

Table VIII also Presents the success rate (SR), fitness evaluation f-eval, and the best solution found by the solver (f-best). The result demonstrates that the BSO-IP method is promising since it found the optimal solution with the lowest fitness function evolution.

TABLE VIII. COMPARISON BETWEEN BSO-IP WITH MI-LXPM, RST2ANU AND AXNUM METHODS WITH MI-LXPM, RST2ANU AND AXNUM METHODS

f	Solver	f-eval	SR	f-best
f_1	**BSO-IP**	**151.96**	**100**	**8**
	MI-LXPM	171	100	8
	RST2ANU	2500	100	8
	AXNUM	863	97	8
f_2	**BSO-IP**	**24.2**	**100**	**-42.631**
	MI-LXPM	99	70	-42.631
	RST2ANU	100	35	-42.631
	AXNUM	456	91	-42.631
f_3	**BSO-IP**	**312.93**	**100**	**-68**
	MI-LXPM	10933	100	-68
	RST2ANU	1489713	2	-68
	AXNUM	45228	82	-68
f_4	**BSO-IP**	**49.7**	**100**	**-6**
	MI-LXPM	671	100	-6
	RST2ANU	2673	75	-6
	AXNUM	13820	95	-6

IV. PROTEIN STRUCTURE MODEL

A. *HP Lattice Model*

The HP model, is such that each amino acid sequence is disconnected as an alphabetic string with H (hydrophobic amino acid) and P (hydrophilic amino acid). The protein adaptations self-keeping away from way on a 3D lattice. The primary thrust of the development of the tertiary structure is the communications among hydrophobic amino acids which are near the lattice yet not adjoining in the sequence, signified as H-H interaction. The free vitality of a protein conformation(X) is communicated by the quantity of H-H interactions. From Anfinsen's supposition [17], the arrangement structures a center in the spatial structure shield dissolvable by hydrophilic amino acids with negligible free vitality. So, the higher the H-H interactions, the lower the free vitality. We expected that the free vitality is equivalent to the smaller number of H-H interactions. HP lattice model is used to solve protein structure forecast problems on 2D and 3D lattice broadly. This study focused on the 3D HP square lattice model. Many meta-heuristics methods tried to solving HP models like genetic algorithm [18] [19] [20]. Example included memetic algorithm [21] , evolutionary strategy method [17] , ACO method [22] and the Tabu search method [23] [24]. A. Baz [21] applied a memetic algorithm to solve the 3D lattice HP model. M.T. Haque [25] used a genetic algorithm to solve the 3D HP lattice model. X. Zhang [23] presented an improved Tabu search for the 3D HP lattice model. T. Thalheim [22] applied ACO to predict PSP of HP model.

P.H.R. Gabrial [17] presented an evolutionary strategy to solve the 3D HP model. Few papers have tried to solve the PSP problem as a mathematical model [26] and [27]. We treat this problem as a simpler mathematical model than other methods; because the our mathematical model is more accurate in finding the solution and is more time efficient.

BSO algorithm solves the 3D HP model, called BSO-HP, as an integer mathematical model. The result demonstrates the strength of BSO-HP to deal with 3D HP model as NP problem.

PSP Problem as Integer Programming Problem

The following equation presents the PSP problem as an integer programming problem.

$$\begin{array}{ll} max & \sum_{a,b} f_{a,b} \\ where & f_{a,b} = \begin{cases} 1, & if\,||M_a - M_b|| = 1 \\ 0 & others. \end{cases} \end{array}$$

where $a = \{1, 2, \ldots, n-2\}$ and $b = \{a+2, \ldots, n\}$.

Three constraints describe the problem: first, the overlapping constraint, which prevents two nodes from being in the same coordinate; second, connectivity constraint, which prevents any cut or change in the protein's sequential arrangement and makes sure there exist a link to other nodes. Finally, the boundary constraint is for refusing the straight structure of the HP model.

- **Overlapping**

$$||M_i - M_j|| \geq 1$$

where $i = \{1, 2, \ldots, n-1\}$ and $j = \{i+1, \ldots, n\}$

- **Connectivity**

$$||M_i - M_{i+1}|| = 1$$

where $i = \{1, 2, ..., n-1\}$.

- **Bounding**

$$\begin{array}{l} length(X) < \ graphboundary \\ length(Y) < \ graphboundary \\ length(Z) < \ graphboundary \end{array}$$

Where *graphboundary*=n/3; and *length(X)*, *length(Y)* and *length(Z)* are the length of the HP model in all three directions, respectively.

B. BSO-HP Algorithm

BSO-HP algorithm solves the PSP problem on the basis of biological theory. Thus, the BSO-HP algorithm has been applied to all procedures in the BSO-IP algorithm besides some procedures to deal with the 3D HP protein structure.

First, protein structure used the following description to write the individual on the BSO-HP algorithm:

- Protein sequence can be written as the chain of amino acid donated as S vector, $S = \{s_1, \ldots, s_n\}$ where n donates the length of the protein sequence, Each s in the S vector may be H or P monomers.

- Denote the direction by vector; X: it contains the direction of each three monomers, X vector has a length of n-2, and each direction is in the range of 0 to 4, where 0 means forward, 1 means left, 2 means right, 3 means up and 4 means down.

- Finally, matrix M involves the coordinate of each node (x, y, z). The nodes in beginning take two coordinates (0,0,0) and (0,0,1).

TABLE IX. Coordinate Nodes in HP Model

M_x	M_y	M_z
0	0	0
0	0	1
1	1	0
1	2	0
1	3	0
0	3	0
0	4	0
0	5	0
0	6	0
-1	6	0
-1	5	0
-1	4	0
-1	3	0
-1	2	0
-2	2	0
-2	2	-1
-2	2	-2

Fig. 3 shows HP model with white nodes for P monomers and black for H monomers. Applying the previous description of the protein structure, then the first S= {HHHHPPHHHHHHHPPPH}, with direction vector X= {2, 4, 4, 2, 1, 0, 3, 2, 2, 4, 3, 3, 1, 3, 2, 3, 2} and coordinate nodes in M matrix is presented in Table IX : From the structure of the protein, we will implement some procedures like initial population and updating individual procedures from the BSO-IP and used in the BSO-HP algorithm are well described below.

1) Initial Population: Every individual is represented by the direction of two nodes generated random values of length n-1, where n is the length of a sequence of protein lattice. For example , X={0, 1, 2, 3, 1, 4, 2,...., 4}. Procedure 4.1 will introduce how we generate the initial solution:

Procedure 4.1: Initial Solution
1. The coordination of the first two nodes is initiated with (0,0,0) and (1,0,0), respectively.
2. For i= 1 to n−1 do Step3.
3. Generated to X_i from 0 to 4 value according to the normal distribution.

2) Updating Individual: The new individual generation method applied two methods, Attract H and move pull methods, depending on the structure of protein sequences. Attract H method considers an intensification process. which is a very important for rapid convergence to the optimal solution. Besides, the move pull method also considers a diversification process, which generates alternative solutions to cover more regions in the search space. The Attract H and the move pull methods are used to generate new solutions in one individual mutation.

a) Attract H Method: Attach H method moves H node location beside other H node location If allowed, and this movement should make the energy of protein with lower values. This procedure is illustrated in Procedure 4.2.

Procedure 4.2: Attract H
1. Adjust all H nodes not adjacent to other H nodes or adjacent to at least one node and put them in the HH vector.
2. Search for an empty location, from the UDLRFB matrix with empty places adjacent to all H nodes.
3. For i=1 to the numeral of H nodes do Steps from Step 4 to Step 6.
4. Move the H node to be adjacent to any other H node if allowed by changing its location.
5.Make changes in the remaining nodes coordinate nodes to achieve the connectivity.
6. Finally, ensure that no overlapping prevention or expansion to accept the movement else refuse the solution.

Fig. 4 presents the effect of Attract H method on the p2 model; Fig. 4(a) shows the p2 model without using Attract H method, and Fig. 4(b) shows the p2 model after using Attract H method. There is a clear difference since energy has a lower value after applying Attract H method.

b) Move Pull Method: Move pull method is considered as an intensification process, focusing on the solution. Its function is to choose three nodes linked together, randomly and then move the three cells in all available directions as presented in Fig. 5 to find the best solution or to make an H node adjacent to another H node with no links between them. This and this improves the resulting solutions. Procedure 4.3 presents the method.

Procedure 4.3: Move Pull
1. Generate a random number rN from 2 to n − 3.
2. Choose three consecutive nodes S_{rN-1}, $S_{rN}$and S_{rN+1}.
3. Detect the recent conformation of these three nodes.
4. Change the conformation from the remaining conformation as presented in Fig. 5 randomly.
5. Change coordinate all remaining nodes until connectivity is achieved.

We generate new individuals, either through one cluster center or more, or through one individual or two. To know which to use,a random value between the (0,1) range is generated. There are two ways to generate the new individual, The first is from one cluster, with the following procedure 4.4 describes the first updating method:

Procedure 4.4: Updating individual
1. Generate random values in the (0,1) range.

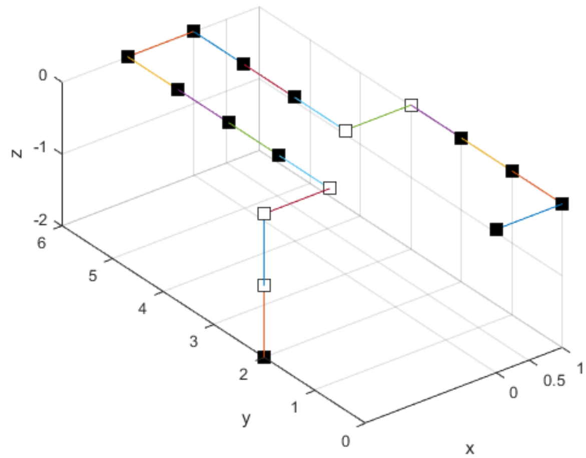
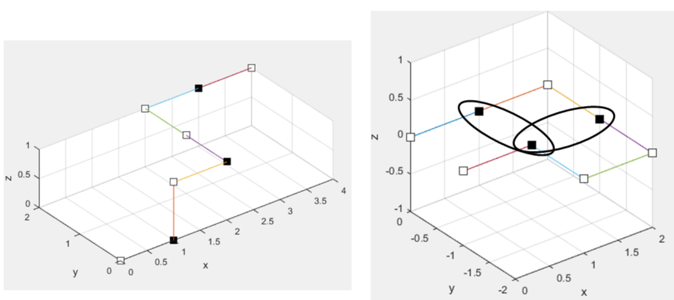


Fig. 3. Example in HP Lattice Model.



(a) (b)

Fig. 4. Apply Attract H Algorithm on Simple Sample HP Model.

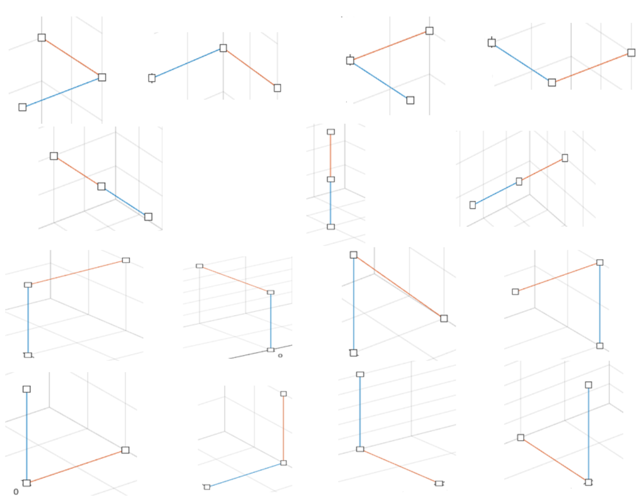


Fig. 5. Conformation on 3 Nodes.

2. If the value generated is less than the predetermined value, Then select one cluster center and update it by using Attract H method using procedure 4.2

3. Else, choose a random individual from the cluster group to update it by using Move Pull method using procedure 4.3.

The second part generates the new individuals from two cluster centers or two individuals of two different clusters. This method is considered a diversification process. The following procedure 4.5 describes the second new individual generation method:

Procedure 4.5: Updating individual
1. Generate random values in the (0,1) range.
2. If the value generated is less than the predetermined value, then select two random cluster centers and combine them using the crossover process.
3. Else, choose a random individuals from two clusters to combine the by crossover process.

V. Experiments and Discussion

BSO-HP algorithm is applied in different HP benchmark models [27, 28, 29] shown in Table XI.

A. Parameter Settings

All parameter values are summarized with their assigned values. These values have a common setting in the literature or are determined through our preliminary numerical experiments. Table X presents additional parameters applied to solve the HP model problem.

TABLE X. Additional Parameters for Solving HP Model Problem

Parameter Operators	parameters values	Description
Move pull parameter		
N_trial	10	Number of trial numbers
N_node	3	The number of the nodes that conformed
Penalty Parameters		
mu	1000	The penalty parameters.
eps	1e-5	The penalty parameters.
Termination parameter		
GenMax	5000 or when reach to the solution	The number of generations

B. Performance Analysis

The BSO-HP method is programmed in MATLAB. It is presented on 14 benchmark HP models, which are shown in Table XI. Table XI shows that our algorithm deals with different lengths of protein sequences.

TABLE XI. PROTEIN SEQUENCES

No.	length	protein sequence
P1	5	HPPHP
P2	8	PHPHPPHP
P3	13	HPPHPPHPHPPHP
P4	17	HHHHPPHHHHHHHPPPH
P5	20	HPHPPHHPHPPHPHHPPHPH
P6	21	PHPHPPHPHPPHPPHPHPPHP
P7	24	HHPPHPPHPPHPPHPPHPPHPPHH
P8	25	PPHPPHHPPPPHHPPPPHHPPPPHH
P9	27	HHHHPPPPPHPPPPPHHHPPPPPPPPH
P10	34	HPPHPPHPHPPHPPHPHPPHPHPPHPPHPHPPHP
P11	36	PPPHHPPHHPPPPPHHHHHHHPPHHPPPPHHPPHPP
P12	48	PPHPPHHPPHHPPPPPHHHHHHHHHHPPPPPPHHPPHHPPHPPHHHHH
P13	50	HHPHPHPHPHHHHPHPPPHPPPHPPPPHPPPHPPPHPHHHHPHPHPHPHH
P14	60	PPHHHPHHHHHHHHPPPHHHHHHHHHHPHPPPHHHHHHHHHHHHPPPPHHHHHHPHHPHP

Table XII presents the results of our proposed BSO-HP method. The best energy values founded in one run are recorded. These results emphasize that our method can find the best-known solution for all HP models except in p6 and p9 models; our method can also find the new optimal solution.

TABLE XII. BSO-HP RESULTS

HP	length	best sol.	HP-BSO
p1	5	-1	-1
p2	8	-2	-2
p3	13	-5	-5
p4	17	-9	-9
p5	20	-11	-11
p6	**21**	**-8**	**-9**
p7	24	-13	-13
p8	25	-9	-9
p9	**27**	**-9**	**-10**
p10	34	-19	-19
p11	36	-18	-18
p12	48	-29	-29
p13	50	-26	-26
p14	60	-49	-49

Sample results presented in Fig. 6 are obtained from different dimensions. For the problem, Fig. 6(b) and Fig. 6(c) obtain the best solution from all algorithms treated with this problem.

The strength of the BSO-HP method is in finding more than one construction of the same model with the optimal solution. Fig. 7 show how the BSO-HP method found multishapes of the best solution. Fig. 7(a) and Fig. 7(b) show multiconformation of sequence p3 model with length 13 and the energy is -5, Fig. 7(c) and Fig. 7(d) show multiconformation of sequence P4 model with length 17 and the energy is -9

C. Comparison Results

BSO-HP method was compared with other methods to exhibit the strength of the method. Table XIII presents the comparison between theBSO-HP method with MCMPSO-TS [28], HGA-PSO [29], and TPPSO [27] based on reaching the optimal solution. MCMPSO-TS method was tested on p1, p2, p3, p4, p5, p6, p8, p10, and p11 and focused on the small HP lengths. HGA-PSO method was tested on p5, p7, p8, p11, p12, p13, and p14. The TPPSO method that was tested on p9, p10. BSO-HP method covered all benchmark models and not only

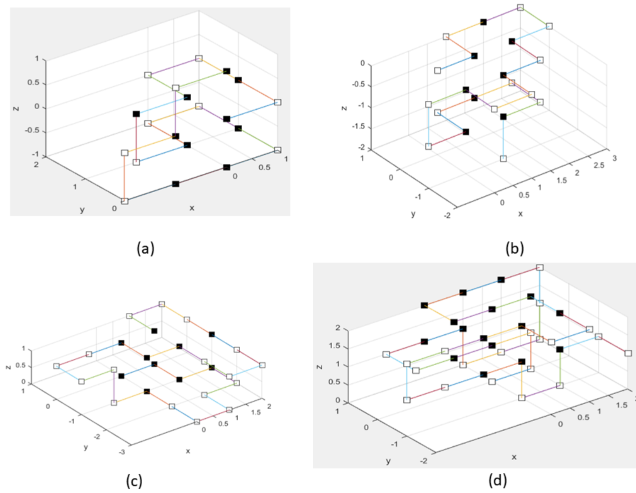


Fig. 6. Conformation of Sequence p5, p6, p10 and p12 Respectively.

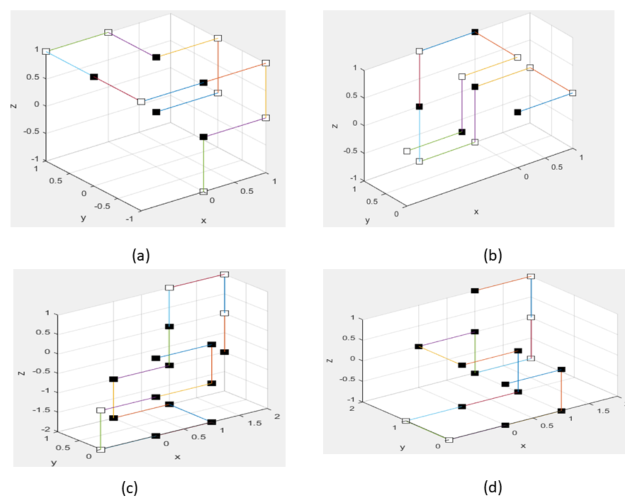


Fig. 7. (a) and (b) Multiconformation of Sequence P3 with Length 13 and the Energy is -5, (c) and (d) Multiconformation of Sequence P4 with Length 17 and the Energy is -9.

found the optimal solution in all models but also got the best solution compared with the rest methods.

VI. CONCLUSION

An adaptive discrete brainstorm algorithm is designed to deal with nonlinear integer programming problems and their applications. The BSO-IP algorithm used the prior knowledge of best solutions in the search space to generate new solutions. This convergence operator helps reach the optimal solution. Several sets of benchmark test problems of nonlinear integer programming problems were tested, and the results proved the promising performance of the BSO-IP. Additionally, the proposed method BSO-HP was applied to solve PSP problems as an NP integer programming problem. The BSO-HP algorithm employed the same procedures as the BSO-IP algorithm, except in some additional procedures to deal with the biological basis in the PSP problem. Numerical results

TABLE XIII. Comparison Between BSO-HP and Other Methods

HP	length	best	MCMPSO-TS	HGA-PSO	TPPSO	HP-BSO
p1	5	-1	-1	-	-	-1
p2	8	-2	-2	-	-	-2
p3	13	-5	-5	-	-	-5
p4	17	-9	-9	-	-	-9
p5	20	-11	-11	-11	-	-11
p6	21	-8	-8	-	-	**-9**
p7	24	-13	-	-13	-	-13
p8	25	-9	-9	-9	-	-9
p9	27	-9	-	-	-9	**-10**
p10	34	-19	-19	-	-	-19
p11	36	-18	-18	-18	-17	-18
p12	48	-29	-	-29	-	-29
p13	50	-26	-	-26	-	-26
p14	60	-49	-	-49	-	49

show that the BSO-HP method is a promising optimization method. Moreover, the BSO-HP method obtained new optimal solutions for two benchmark protein sequences. We will apply our proposed method to the other types of PSP problems as the 3D face-centred-cube HP model. Also, The proposed method obtained multishapes of the same protein sequence with the same lowest energy, a feature important to biologists. We would like to improve our proposed method to be able to help biologists in a laboratory.

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Design of a Web System to Optimize the Logistics and Costing Processes of a Chocolate Manufacturing Company

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***Abstract*—The research work is focused on the solution to a problem that a company dedicated to the manufacture of chocolates has. This company does not have a computer system to help it improve its management. The information recorded from the logistics and cost processes is stored locally in Excel files, and the information from the operational processes is stored in bond sheets and then transferred to Excel files. Since information is very valuable for a company, it must be orderly, accessible, and secure. Therefore, the Scrum methodology was implemented for the development of a prototype web system for the company. The prototype of this web system was developed with Adobe XD software because it is easy to use and complete for the design of interfaces for web pages. As a result of the development of the prototype of the web system, there is a record of information in an orderly, interactive, easy, fast, and above all safe way. And it was concluded that the management of the logistics and cost area of the company was optimized and improved.**

Keywords*—Adobe XD; costing; logistics; scrum methodology; web system

I. Introduction

The main objective of any commercial enterprise is production, so the aim is to establish trade chains or relationships that will increase its profits [1].But currently, many companies perform their operational processes of production and storage of information traditionally, because they do not have modern machines or an effective computer system that minimizes time and improves the management of processes in most areas. Mainly in the area of logistics, which would help to reduce costs and increase competitiveness. Therefore, the logistics management of the company is important because it is the core of modern supply chain management, and serves as a platform that has in the origin and consumption [2].

As in any company, information is very important; therefore, it must be stored properly so that it does not run the risk of being lost. For example, in the event of a fire, if the information is stored on bond paper, it would be lost when it burns. Concerning saving information in Excel files locally on a computer, there is also a risk of being infected with a malicious virus, generating another loss of valuable information.

CATICAO, a chocolate manufacturing company, has not implemented a computer system that allows it to store the data of its processes (inventory, warehouse). Since it does not want to lose any important information, it saves them in Excel files, and the information of the operational processes is saved in bond sheets.

When you have to perform the process of making chocolate the first thing is to select the cocoa according to its weight, after that you will have to roast, control the time that is done, and so on all the processes. All this is done manually, so in this process it takes a lot of time to pass the information from the bond sheet to Excel, therefore, you are wasting time. In addition, they do not have an inventory and stock control software in the logistics area, therefore, it always takes more time to perform this process, which is very important to verify the availability of products, inputs, and supplies.

In business logistics, there are different activities and costs. The amount of these costs and the percentage of the total cost, where requires the magnitude of the company and the activity it performs [3]. In addition, different factors require companies to incur cost overruns, for example, storage, inventory, purchasing, distribution system, and transportation. As time goes by, these factors will represent a problem, especially when the company's management does not have planning, programming, and control of activities [4].

In the same way, the company has problems in cost management, it wants to know the direct and indirect costs in the production of the product to see how it could reduce them and adapt a competitive selling price of the product. But there are some differences in logistics costs across companies in multiple industries [5]. And some studies claim that the share of company sales revenue ranges from 6 to 25%

On the other hand, if the company does not have all the information ordered and available at all times of the logistics and cost processes, it will not be able to generate reports with which to make important decisions for self-improvement. Therefore, the importance of this web system is focused on the improvement of the company's management in the logistics area, to analyze the company's direct and indirect costs to reduce them, as well as better management of the company's stock.

The objective of this article is to design a web system to optimize the information management of the processes of the logistics area and reduce the costs of the company CATICAO.

The article is composed of sections. In Section II, the Scrum methodology will be developed, in Section III, the case study will be developed, in Section IV, the discussions will be developed, in Section V the results will be developed and finally, in Section VI, the conclusions will be developed.

II. Literature Review

The author [6], explains that currently, companies do not perceive the price increases of energy sources or fuels for heating, cooling, and air conditioning. Therefore, companies are concerned about energy issues and will have to analyze their logistics to reduce costs and increase their competitiveness. He also says that logistics is a process-oriented business and therefore proposes a measurement system that supports decisions for the evaluation of costs to each logistics process. The system allows the calculation of social, environmental, and economic costs to ensure sustainable logistics.

The environment is increasingly competitive and, that includes companies, and that better management of the logistics chain must be adopted, with the main objective of increasing profits, maximizing benefits, and minimizing costs, such as transportation and storage. In his work, he proposes a cloud platform for this supply chain process to support decision-making. Also, he describes the structure of the platform that has multiple layers and contains it in a set of web services that provides a link between the applications of the technologies, and with that manages to enable the transfer of data by protocols understandable to others [7]. As a scenario in this project, a delivery process problem was formulated, and a packaging algorithm was proposed to improve vehicle loading as explained by.

The author [8], explains about the administration of a farm that will be able to register all the costs that there is in the production, in a format manually that the company has, in addition, the versatility does not contribute too much in the management, for that reason, the execution of the web system that will allow improving the costs that this of chronological, organized and systematic form is going to be very necessary for the execution is being realized.Therefore, the research methodology is adequate, since the techniques that are in data collection, apart from the survey that has the customer requirements, based on which is developing the web system that can calculate the cost of production that has. ProCCSys, will suitably allow managing the process that is being productive, at the same time that it is facilitating in the registry, according to what is happening in the field, for the obtaining of the production cost that is formally and suitably.

The project consists of the creation of a cost system for the Industrial Accessories Company, which focuses on the production, marketing, and assembly of products [9]. The project analyzes and organizes the corresponding information that occurs in the production process, taking into account the considerations and aims to develop one of the tools that allow not only to focus on knowing the costs but also to monitor the areas where there is more cost invasion so that it can improve the strategies as explained by.

Finally, it was concluded that in order to optimize the information management of the logistics area processes and reduce costs, a web system has to be designed.

III. Methodology

This section will describe the methodology and tools that will be used to develop the design of the web system that will optimize the processes of the logistics and cost area of the company CATICAO.

A. *Scrum Methodology*

This methodology was selected because it brings together a cross-functional team, which means that members must have a minimum of experience that can perform different functions. They should also be responsible for self-management as a team [10].

One of the most important features of Scrum is that it initiates the collaboration you have with consumers in place is not very flexible for contract business. Therefore, it is essential to have enough capacity in one of the possible results for the alteration to follow strictly with what will be planned, starting at the beginning of the project since it is very changeable [11]. Keeping in mind as the objective that the customer will observe as a result that will be able to make decisions in the whole project.

1) Roles:

- Product Owner: This is the person who will be in charge of making decisions and will recognize the client's business and vision.
- Scrum Master: The person in charge of verifying that the Scrum models and methodology work.
- Development Team: They are grouped by 5 to 9 people who have the power to organize and take the proper objectives to achieve a common goal.

2) Meetings:

a) Backlog Planning: The system requirements will be defined and the sprint 0 will be planned, since the objectives will be defined.

b) Sprint Follow-up: In this phase, daily meetings will be held in which 3 questions must be answered.

c) Sprint Review: At the end of the sprint, it begins with the increase that was made and it will be generated, then the final result will be displayed [12].

3) Phases:

a) Sprint Planning: It will be allowed to establish objectives of the product backlog, that is, the list of tasks that will be developed in our project in a certain time [13]. In addition, the meeting will define what function the planned increase will have and how it will be executed in the increase and at the end it will be defining the objective that the Sprint will have.

b) Sprint development work: In the execution of the methodology, the Sprint Backlog tool will be used and each person part of the team will inspect the work that the rest will be developing [14] also, When our sprint work is being carried out we must observe that it has no changes last minute, because it could affect the objectives proposed in the project.

c) Sprint Review: It will be allowed to analyze and evaluate the results that were developed in the sprint, due to this, it will be determined if it has been done well or it will be necessary to return to the planning phase to improve the sprint [7]. In the execution, it will be carried out at the end of each Sprint that will be developed in 3 hours, to be able to supervise the increases in detail.

d) Sprint Retrospective: In the three-hour meeting of the Scrum team in which they will begin to analyze how the communication was between the system, the process, and the set of tools [15].

In Fig. 1, it will be represented in the orders that are in process, how it will be developed, and the use that the Scrum methodology tools will be having.

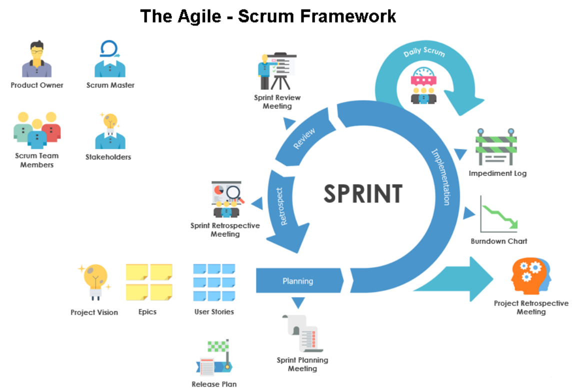

Fig. 1. Scrum Methodology Processes.

B. Prototype Tools

In the designs of web systems, Adobe XD will be used, it is a graphical editing tool that will serve as an aid for the development of design interfaces and prototypes of web applications. It allows designers to work much better so that they can navigate with a minimum error and in less time and one of the advantages is that it has pre-visualization tools that will allow you to look at the project when it is completed [16].

C. Technological Tools

1) PHP: The main reason for the famous PHP, which is a programming language that performs scripting for a web system [17], is its broad support for various databases, making it easy for developers to create database-driven web pages quickly and efficiently without much complexity.

2) MYSQL: It allows database developers or data architects to be able to visually design, generate, model, and modify databases [18], including those that have a data modeler required to create database models .

IV. Case Study

In the research part, it will be explained in a way that it will be detailed as this carried out in the prototype for the web development of the company CATICAO, with the Scrum methodology, because, that all the execution will be carried out in a manner that is accepted in the requirements to have the new prototype. Since, then, the planning in the Sprint of each one that has the modules that is going to be exercised and the estimation of the times that is going to be used in each of the stages that it has will be finishing I develop them.

A. Sprint Planning

In the section, the User History that will be in the specification of the functions that the systems will have and will have the system that will have finalization of the contribution that the clients will have and will have The team that is going to increase the processes that the project has, consequently, they are in fast ways that will supervise the requirements that will be without executing the large documents that they have, then the following will be placed formats that will have the user's story As I want and for; that will be developed in the case study will be shown in Table I.

TABLE I. User Story

Description	N°	Priority	Story Points
As a User, I want to enter the web system through a login to access the software.	1	3	7
As a User, I want to register to log in to the system.	2	3	11
As a User, I want a stock sub-module to be able to register the quantity of the products.	3	2	10
As a User, I want an input stock sub-module to record the quantities and movements of production inputs.	4	2	8
As a User, I want a sub-module to calculate indirect costs such as indirect labor, materials, and elements to know the selling price of the product.	5	3	15
As a User, I want a sub-module to calculate direct costs such as raw materials, inputs, and direct labor to know the selling price of the product.	6	3	16
As a User, I want a sub-module to report stock and movements of inputs and finished products to control the warehouse.	7	5	18
As a User, I would like a reporting sub-module for direct and indirect cost queries of the company according to the period to have better control.	8	6	19

1) Time Estimates: In the section, the entire duration that will be approximated of each one that has the Sprint will be displayed [19], for them, the entire Table III will be indicated. The good methods that will be used in a way that will be better known than they are in the Scrum methodology are the Poker planning since it will be used as the arbitrary size dimension to be able to supervise and correct the difficulties that have in the amount of size of the story and that it has as that of a value that makes sense because they have the team of a good execution .

The estimate of the project had as a result of the 3 months since they have user stories since they were estimated between 1 and 2 weeks according to Table II.

TABLE II. Product Backlog

Interface	Duration
Mobile application for learning development	3 months and 2 weeks
Sprint 1: Login Interface	1 week
Sprint1: Registration Interface	1 week
Sprint 1: Home Interface	1 week
Sprint 2: Requisition Interface	2 weeks
Sprint 2: Stock interface	2 weeks
sprint 3: Direct Cost Interface	2 weeks
Sprint 3: Indirect Cost Interface	2 weeks
Sprint 3: Stock Reporting Interface	2 weeks
Sprint 4: Cost Query Report Interface	2 weeks

2) Product Scope: It is understood that the product is taken as the result of a project. Due to all functions since it is going to be having that originate from many requirements that the client or the company that is going to be executing have because they are indicating how what they are going to be wanting from the product [20]. Therefore, if you are going to be wanting, you must know that the scope must have the products that are going to be fulfilled, to be verifying and evaluating that all the requirement is planned so that they can be included within the product that will be the results, that is, it will be as it will be requested.

Fig. 2 will show the estimates of the time it will take for the team to have the user history points so that the scope estimates are noted down to the smallest detail.

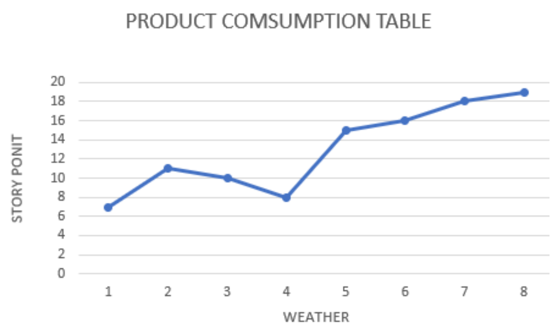

Fig. 2. Product Scope.

B. Sprint Development Work

In this phase of the methodology, 4 Sprints were developed and they are the following:

1) Sprint 1 (Login, Registration and Home): In this Sprint the prototypes of the login, registration, and user start interfaces were developed, the user will be able to enter his account with an email and a password as shown in the login interface in Fig. 3.

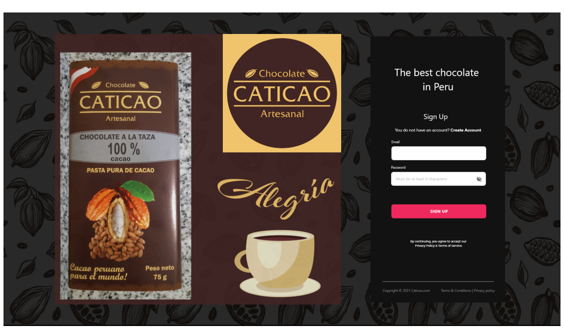

Fig. 3. Login.

If you do not have an account you can register, as shown in the registration interface in Fig.4, the user has to enter his data such as name, email, and password.

In the Home interface, the user can see the summary of some system processes such as the list of requisitions, costs, activities performed, and notifications as shown in Fig. 5.

Fig. 4. Registration.

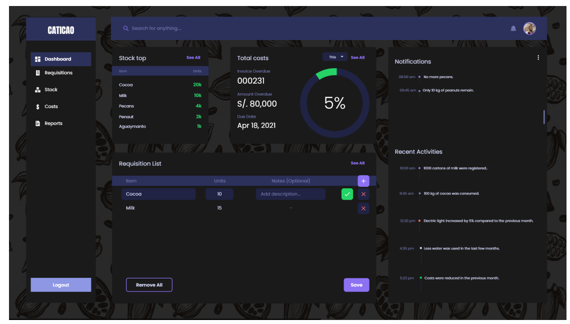

Fig. 5. Home.

2) Sprint 2 (Requisitions and Stock): The interface designs for the requisition and stock interfaces were developed. Fig. 6 shows the Requisitions interface where the raw materials and supplies needed for production are recorded.

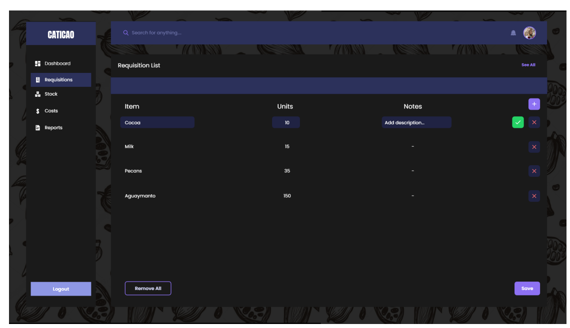

Fig. 6. Requisitions.

Fig. 7 shows the Stock interface where the user can see the raw materials and inputs that are available.

In the interface of adding a new item to the Stock, the name of the item and the quantity will be added as shown in Fig. 8.

3) Sprint 3 (Direct and Indirect Costs): The designs of the direct and indirect cost interfaces were developed, the user can visualize in the direct cost interface, the costs of the month of raw material, inputs, and workers as shown in Fig. 9.

Fig. 10 shows the indirect costs interface, the user can see the costs of water and electricity supplies, as well as other costs such as rent and transportation.

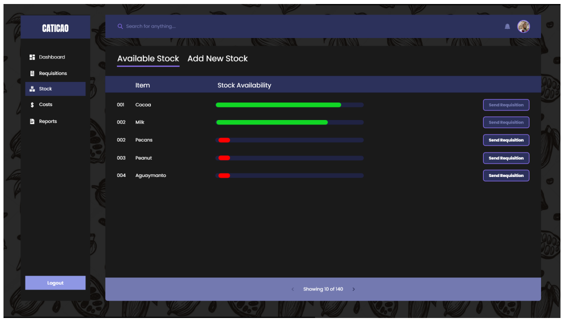

Fig. 7. Stock.

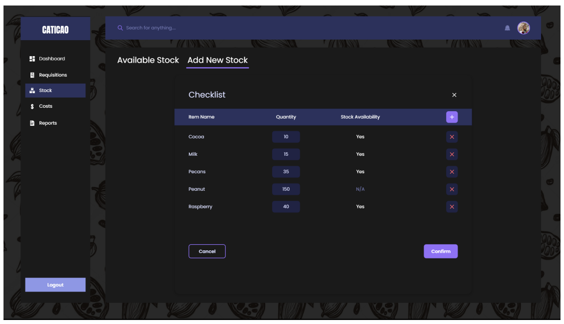

Fig. 8. Add Stock.

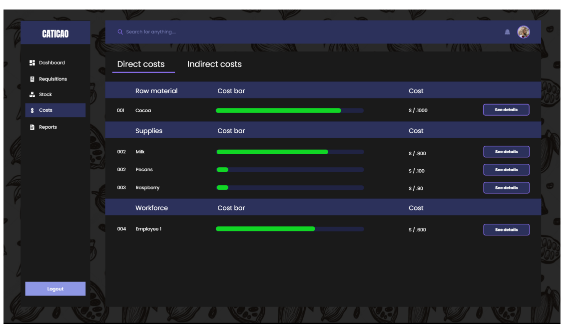

Fig. 9. Direct Costs.

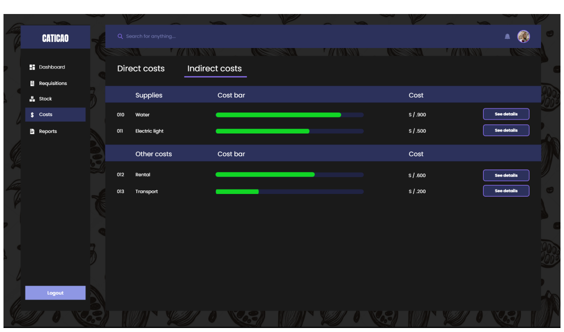

Fig. 10. Indirect Costs.

4) *Sprint 4 (Reports):* The report interface designs were developed, the user can see the stock report in a bar chart with a date filter as shown in Fig. 11. Fig. 12 shows the cost report interface where a dot chart of the total costs with a filter by year is shown.

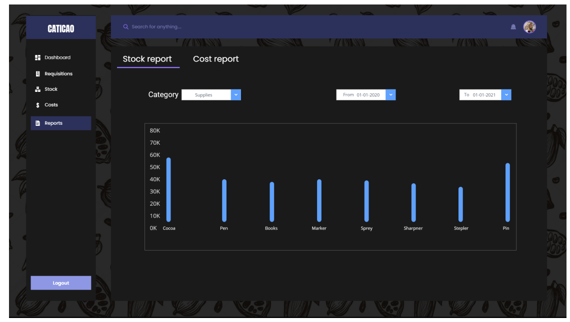

Fig. 11. Stock Report.

Fig. 12. Cost Report.

C. Sprint Review

At the end of the Sprint, it is reviewed by all team members, the inspection time is between 2 and 3 hours, also a member of the group will evaluate each task to be developed and decide the need for any change. Finally, the team members will explain each of the processes at a detailed level and the implemented solutions.

D. Sprint Retrospective

The team member will supervise each process and technique that will be implemented during the execution of each Sprint. For example, the use of PHP as a programming language, MYSQL as database manager, or the Adobe XD a tool that was used for the design of the web system interfaces. In addition, new methods are suggested to improve in each Sprint development of the project.

V. Discussion

In this section, a comparative analysis will be made with other research works and other agile or traditional methodologies.

A. About Case Study

The prototype design was done with Adobe XD software, because it is a tool specialized in the development of web interface prototypes. There is other software for the design of the prototype such as Balsamiq which is easier to handle, but it is limited to a basic design. On the other hand, comparing the design of the modules of the [21] research work, their modules do not have a complete design compared to the elaborate design of the web system, which is well elaborated, and with its detailed modules. Although there were not many similar types of research on logistics and costs in a web system, the design was made by referring to several types of research with little similarity.

B. About the Methodology

The best-known methodology among the Agile family is Scrum. This methodology does not explicitly define development practices, so it offers researchers the opportunity to adopt and adapt practices from other models [22].In addition, Scrum is recognized for overcoming certain shortcomings of traditional software development methods [23].

Scrum, RUP, and XP methodologies are the most adapted for agile development [24]. When compared, each has many positive features as well as shortcomings. For example, Scrum has limitations in engineering practices, XP does not provide much in the way of management, and RUP has drawbacks for small projects, slow responses to changing requirements, and tends to spend more budget.

VI. Results

Next, we will show the results that will be expected concerning what is being planned in the development of the research work within the case study and the Scrum methodology, taking into account the web system that is being developed and implemented.

A. About Case Study

The objective of the case study was to develop a web system to optimize the area of logistics and costs for the company CATICAO, improving the speed of the processes so that they can reduce the time spent on developing each employee.

According to the implementation of a web system in Chimbote that was applied to the workers, the following question was asked: Is it necessary to have a web system to manage the warehouse process both internally and externally? 90% of employees voted that it was necessary to have a web system to streamline the processes, and 10% voted no, according to Table III [25].

TABLE III. Survey Graph

Graphix No.		
yes	18	90%
not	2	10%
total	20	100%

In addition, it can be seen in Fig. 13. the need for improvement of the current processes that are in a web system for the company.

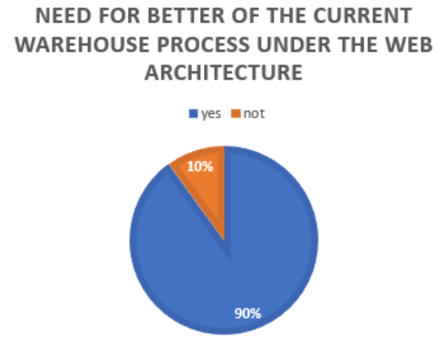

Fig. 13. Need for Improvement of the Current Warehouse Process.

B. About the Methodology

Implementing the Scrum methodology has generated better efficiency. In addition, the project will help to streamline the data processes in a warehouse system with technology at the end of the projects can be expected to have the modules of warehouse controls, where operators will be able to perform basic activities [9].

VII. Conclusion

In conclusion, the design of the web system interface was carried out to improve the processes of the logistics and cost area of a company that is dedicated to the production of chocolates, in order to solve the loss of time in each process they performed when they did it manually. It was developed with Adobe XD tool which is popular for interface design. In addition, the Scrum methodology was included, which allows for better teamwork, in an orderly manner and with anticipated results in the project.

VIII. Future Work

As future work is required to increase more modules to provide solutions for different areas, for example, the sales to make invoices and sales slip for better functioning of this area.

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A RED-BET Method to Improve the Information Diffusion on Social Networks

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***Abstract*—Information diffusion in the social network has been widely used in many fields today, from online marketing, e-government campaigns to predicting large social events. Some study focuses on how to discover a method to accelerate the parameter calculation for the information diffusion forecast in order to improve the efficiency of the information diffusion problem. The Betweenness Centrality is a significant indicator to identify the important people on social networks that should be aimed to maximize information diffusion. Thus, in this paper, we propose the RED-BET method to improve the information diffusion on social networks by a hybrid approach that allows to quickly determine the nodes having high Betweenness Centrality. Our main idea in the proposed method combines both the graph reduction and parallelization of the Betweenness Centrality calculation. Experimental results with the currently popular large datasets of SNAP and Animer have demonstrated that our proposed method improves the performance from 1.2 to 1.41 times compared to the TeexGraph toolkit, from 1.76 to 2.55 times than the NetworKit, and from 1.05 to 1.1 times in comparison with the bigGraph toolkit.**

***Keywords*—Information diffusion; graph reduction; betweenness centrality; parallel computing**

I. Introduction

Information diffusion is a key in social network analysis with many potential real-world applications. For example, it can be used for predicting large social events such as the Arab Spring [23], for improving the recommendation performance of products and services, and for maximizing advertising effect to individuals. However, it is difficult and time-consuming to be able to make the information diffusion forecast. The cause of this problem is the characteristic of the social network as a relatively large-scale graph with a large number of members (number of vertices) and number of relationships (number of edges) leading to the computation of the parameters for forecasting diffusion takes a lot of time [3].

Graph reduction, based on the application of graph theory [31], [36], is the basic and effective technique to minimize the time to calculate parameters in graphs and the time to analyze information diffusion forecast. Reducing unimportant vertices and edges on the graph will make the calculation faster. It is critical, however, to demonstrate that the reduction does not affect the graph's overall model.

Besides, in the problem of information diffusion, many parameters need to be calculated to conclude the diffusion. One of the most important parameters is centrality degree to identify the most critical (most central) vertice in a graph [4], which means the center of a pandemic, the main node on the Internet, or an influential person in social networks... [22] demonstrated the influence and the importance of centrality computation in the problem of disease diffusion as well as information diffusion.

Among the indicators of centrality degree [24], [28], besides the Closeness Centrality, the Eigenvector Centrality, the Betweenness Centrality (BC) [12] is an important measure, valuable in determining a vertice is an intermediate bridge when establishing the shortest relationships (path) between other vertices. This centrality has been used in many practical problems. Such as, during the current Covid-19 pandemic, the authors in [32] used the BC indicator to identify subjects that need to be localized soon to proactively prevent the spread of SARS-CoV-2 coronavirus. In [13], [19], authors proved that BC has an important influence on the acceptance and diffusion of information. But, to compute BC for all vertices in a graph, we must solve the problem of finding the shortest path on all pairs of vertices in the graph, a process that takes a long time with large graphs.

To accelerate the computation, a number of researches have been actively performed, focus on the orientations such as graph reduction [1], [14], [33], approximating [6], [17], parallelizing using GPU [7], [15], [25] or using a high-performance computing platform [2], [11]. Based on some previous studies, in this paper, we propose a hybrid method to improve the information diffusion on social networks by a hybrid approach that allows us to quickly determine the nodes having high BC. Our method combines two processes: graph reduction and BC parallel computing to accelerate the computation, analyze information diffusion forecast while proving that our method did not affect the overall model of the graph.

The remainder of this paper is divided into four sections as follows: Section II describes fundamental concepts and definitions; other related works will be also presented in this section. Our hybrid method to improve information diffusion by graph compression and quickly determining the BC on social networks will be given in Section III. Section IV is dedicated to present the experiment results and evaluations confronted with the bigGragh and NetworKit, TeexGraph toolkits. Finally, the conclusion and future works will be presented in Section V.

II. Preliminaries and Related Work

A. Notation

Social networks are represented in the form of graphs. In which, the graph is a flexible data structure, represented as a set of vertices and edges, otherwise known as a set of nodes and their relationships [26], [27].

Definition 1.1. In graph theory, a graph G, denoted $G = (V, E)$, is made up of a set of nodes V and a set of edges E connecting nodes with $E = \{(v_i, v_j)|v_i, v_j \in V\}$. This structure allows us to model all kinds of problems, from building disease transmission maps, mapping systems, and graphing of the relationships on Social Networks,...

For the convenience of evaluation, in this paper, we only focus on unweighted graphs, but can be directed or undirected. It means:

- Unweighted Graph: is a graph with no value assigned to each edge.

- Simple Graph: is an unweighted graph and only has exactly one edge between two vertices.

- Connected Graph: is a graph of existence path (u, v) from vertice u to v for all pairs of vertices $u, v \in V$.

In this paper, we also use some concepts such as:

- Degree of the vertice, denoted $deg(v)$ is the total number of edges to and from vertice v. Due to considering only graphs, the degree of the vertice v is also the number of vertices adjacent to that vertice. The vertice v is called the hanging vertice if $deg(v) = 1$ and is called the isolated vertice if $deg(v) = 0$. In a directed graph, the degree of the vertice is further divided into d_{out} and d_{in}.

- Path is a series of vertices and edges from vertex u to vertex v in the graph without any vertices or edges repeated.

- The shortest path between two vertices u, v, denoted $dist(u, v)$, with an unweighted graph, the shortest path is the path with the smallest number of edges from u to v. If u, v overlap $dist(u, v) = 0$, if u, v don't link dist $(u, v) = \infty$.

- Adjacent list $\Gamma(v)$ is a list of vertices adjacent to v, also known as its neighbor set of v.

Definition 1.2. The Degree Centrality of vertice v is the number of edges associated with vertice v. This measure is determined by the following formula:

$$CD(v) = deg(v) : v \in V \tag{1}$$

Thus, the Degree Centrality of a vertice is the degree of that vertice. With the directed graph, this measure is also divided into CD_{out} and CD_{in}. For social networks, the Degree centrality is a person's number of friends on Facebook or the number of followers on Twitter.

Definition 1.3. The Betweenness Centrality of a vertice v is calculated by the following formula [29]:

$$BC(v) = \sum_{s \neq v \neq t \in V} \frac{\sigma_{st}(v)}{\sigma_{st}} \tag{2}$$

where σ_{st} is the number of shortest paths from vertice s to t and $\sigma_{st}(v)$ is the number of shortest paths from vertice s to t through vertice v.

Thus, BC is the number of intermediaries one person takes on when establishing the shortest relationships among others [12]. In his study, Linton Freeman conceived that the vertices with high probability lying on the shortest path between two randomly selected vertices in the vertice set V would have the most BC.

B. Related Work

In the studies of accelerating computation and analysis, graph reduction is considered a highly effective method. The essence of graph reduction is to remove/replace unnecessary/unimportant vertices and edges to obtain a more compact graph and retain important vertices and necessary properties of the graph.

Feder and Motwani in [33], Adler and Mitzenmacher in [14] mentioned reduction by graph compression. In it, [33] offers a compression method by using a partitioning algorithm for the bipartite graph. The author in [14] put the compression problem on the problem of finding the minimum spanning tree. Basically, the graph compression method results in a more compact graph, however, it often serves the problem of graph storage (data or structure). For the social network analysis problem with constantly changing data, the graph compression is not suitable because continuous conversion between the original graph and the compressed graph is not positive.

Gilbert and Levchenko in [1] gave several graph reduction methods with two algorithms KeepOne, KeepAll, and the method of deleting redundant vertices RVE (Redundant Vertex Elimination). In it, the KeepOne algorithm is similar to the method of Adler and Mitzenmacher, that is to find a minimum spanning tree for the graph. This method allows to keep the maximum number of important vertices and the vertices located between those important vertices, however, the biggest disadvantage of this method is that it does not preserve the shortest path between the two vertices. In contrast to it, KeepAll is an algorithm that allows retaining the shortest path between important vertices. It can be said that the two algorithms have their own strengths and are suitable in certain cases (for example, KeepOne will be suitable for the network planning problem, KeepAll is suitable for the problem of finding the shortest way in traffic), however, they are not suitable for social network analysis problems. RVE is the closest method to analysis and computation on social networks, this method allows the elimination of vertices that have a common adjacent one. The method is often applied in communication network reduction with the elimination of unnecessary redundant nodes. If applied in social network analysis, it can delete the unimportant vertices. But besides that, if the important vertices have a common adjacent one, one of which is also removed.

In previous research, we relied on the idea of the redundant vertex elimination - RVE method, which is to reduce the graph based on the replacement of the equivalent 1-degree vertice. That is, in the reduction process, we only consider the hanging vertices, $deg(v) = 1$ equivalent to $BC = 0$. In that research, we have given the solution, described the algorithm, and experimented on the small simulated network of 100 vertices. In this paper, in addition to the parallelization, we also came up with the specific pseudo-code algorithm, proved the effectiveness of the method in the problem of information diffusion, and experimented with it on some larger datasets.

For the quick BC computation, this is also the content that many researchers are interested in. At first, there are several methods to solve APSP problems, such as Floyd-Warshall's algorithm, Johnson's algorithm [34] and Brandes algorithm [35]. Compared with calculating APSP by Floyd-Warshall algorithm (computation complexity $O(|V|^3)$)) and Johnson's algorithm (complexity $O(|V|^2 log(|V|) + |V||E|)$)), then Brandes' algorithm with time complexity is $O(|V||E|)$ on an unweighted graph and $O(|V||E| + |V|^2 log(|E|))$ on a weighted graph is considered the most effective algorithm to compute BC for all vertices in graph.

Riondato and Kornaropoulos in [17], Mahmoody, Tsourakakis and Upfal in [6] give an idea of the fastness approximation computing the BC based on sampling technique. According to this method, some of the shortest paths will be randomly sampled, thereby applying the algorithm to estimate the distance between the vertices and approximate the BC.

Bernaschi, Carbone and Vella in [15], Fan, Xu and Zhao in [25], McLaughlin and Bader in [7] gave advanced solutions to speed up BC computation by parallelizing computation processes using GPU graphics processors. The author in [15] also combines multiple GPU sets and parallel models using distributed memory MPI to speed up computation. Notably, these methods all use the classic Brandes algorithm.

Ching in [2], Wei, Chen, Zhou, Zhou, and He in [11] suggest using the GraphLab and Apache Giraph toolkits on complex computation infrastructures such as cluster computer systems or high-performance supercomputers. However, these toolkits are mainly designed to analyze very large networks up to trillions of edges, not really efficient for computation with real networks not too large as Facebook.

In addition to the above methods, improving BC computation performance can be applied by parallelizing the NetworKit toolkit or the TeexGraph toolkit for large-scale social network analysis. These tools all use a parallel shared memory model and use the OpenMP library to parallelize BC metrics. One of our research in [21] is the parallelization of SSSP calculations in Brandes algorithm with parallel thread programming model on CPU and using CilkPlus library.

In the above studies, there is currently no research focusing on combining the process of graph reduction and improving the performance of calculating the betwenness centrality when solving the problem of information dissemination on social networks. This is the main motivation for us to propose a method overcoming this challenge in this paper.

III. RED-BET HYBRID METHOD TO ACCELERATE THE COMPUTATION IN INFORMATION DIFFUSION PROBLEM

Based on the above analysis, in this paper, we propose a hybrid method to improve the information diffusion on social networks represented by an unweighted graph. This method is based on the combination of two processes:

i. The graph reduction is based on replacing the equivalent 1-degree vertices.

ii. Paralleling SSSP calculations in Brandes algorithm with parallel thread programming model on CPU using CilkPlus library.

Since then, we call the proposed hybrid method namely **RED-BET** .

In this study, we still use a graph data structure approach like [20] to improve the cache hit rate when referring to graph data. Thus, the large-scale graph $G = (V, E)$ is organized by the adjacent vertex lists where each vertex is assigned an identifier from 0 to $|V|-1$. For edge data, sorted vertex vectors are used to represent the graph edges. That means the graph edges are structured in the vectors array $Edges[u]\ \forall u \in V$. For real-world social networks, such as Twitter or Facebook, the vertices number is small than 2^{32}. Therefore, the graph data is allocated by a 4-byte integer vectors array and our method can analyze a graph with the largest number of vertices possible being 2^{32}.

A. Graph Reduction

The first step in the reduction of the graph is to determine the equivalent 1-degree vertices. 1-degree means hanging vertices $deg(v) = 1$ and equivalent mean that they must have a duplicate set of adjacent vertices $\Gamma(v)$. And since they are 1-degree vertices (with a single adjacent vertice), we can say that we need to find the hanging vertices that have a common adjacent vertex.

To do this, we need to proceed with graph searching [30], [18], [9]. While considering whether to use breadth-first searching (BFS) or depth-first searching (DFS), we found that the first phase of Brandes' BC computation that we improved was the browse by BFS. Therefore, we proceed to integrate the graph reduction into the graph searching phase, ie also using the BFS method.

After determining the equivalent vertices above, replacing them is understood that we will choose a single vertice to represent, or that is, delete the equivalent vertices and leave a single vertice. This reduction reduces the size of the graph, which in turn will certainly change the result of the BC computation of vertices. However, there are two reasons for us to decide to still reduce the graph. Firstly, the vertices that we replace are the hanging 1-degree vertices, the Betweenness Centrality $BC = 0$, meaning the vertices are not important, their removal does not affect the graph too much.

Secondly, in analyzing the social network graph, we care about which vertice is "most important", or which vertice has the highest centrality or the highest BC not about what is the exact BC of that vertice. Our reduction method allows to ensures that the "most important" property of those vertices is preserved.

Thus, the graph reduction algorithm is illustrated as follows:

Algorithm 1: Graph Reduction Algorithm

Input: $G = (V, E)$, is organized as an vector array $Edges[][]$
Data: queue $Q \leftarrow$, stack S create the hollow (empty) and its able to contain $|V|$ vertices
Output: $Edges[][]$ of G have been reduced

```
/* Phase 1. Graph reducing */
foreach v ∈ V do
    while Q not empty do
        v ← Q.pop(); S.push(v) ;
        foreach
         w ∈ Edges[v]&&Edges[w].Size() = 1 do
            if u ∈ Edges[v]&&Edges[u].Size() = 1
             then Edges[v] ← Edges[v]\{u} ;
             /* delete u from Adjacent
             list of v */
            Edges[u] = {} ; /* delete vertice
             u */
            ;
        end
    end
end
return Edges[][];
```

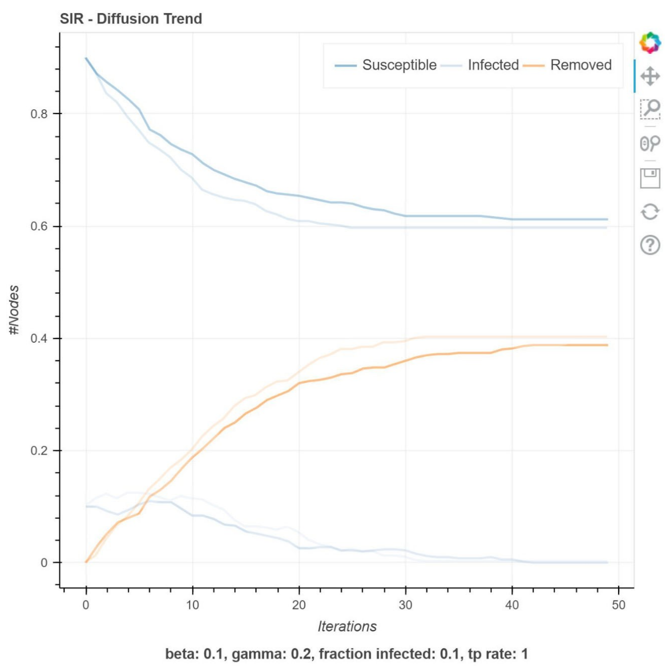

Fig. 1. Test with Random Graph of 500 Vertices.

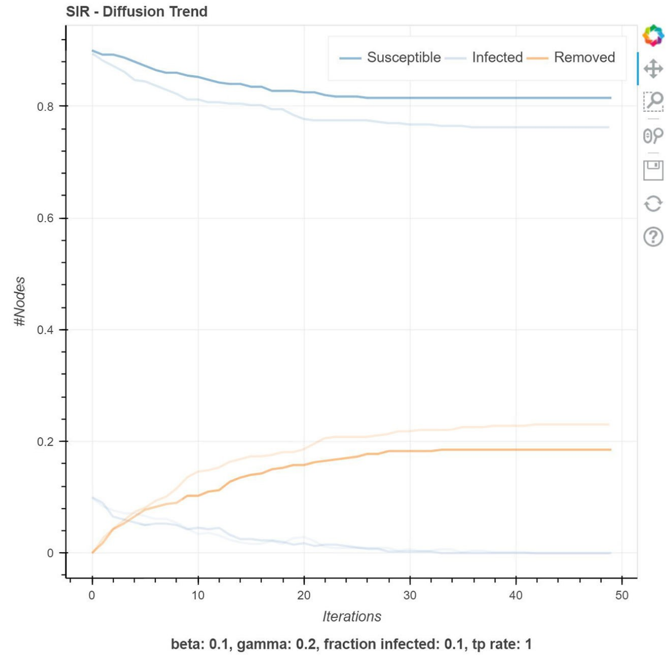

Fig. 2. Test with Random Graph of 400 Vertices.

TABLE I. COMPARE THE DIFFUSION TIME (SECONDS)

Times	Graph with 500 nodes		Graph with 400 nodes	
	Before	After	Before	After
1	1.30	1.25	1.28	1.20
2	1.27	1.23	1.26	1.20
3	1.28	1.25	1.25	1.19
4	1.32	1.24	1.26	1.20
5	1.28	1.22	1.25	1.18
6	1.28	1.24	1.28	1.21
7	1.29	1.23	1.24	1.18
8	1.32	1.25	1.24	1.19
9	1.31	1.25	1.25	1.18
10	1.30	1.24	1.26	1.20

To prove the effectiveness of graph reduction in the Information diffusion problem, based on the method and library (NDlib) in [8], we tested the information diffusion process on some random graphs using the SIR model and compare it with that process when the graph is reduced. For the first time, we used a random graph of 500 vertices, the probability to generate edges is 0.005, with 50 times the information was diffused. The results are shown in Fig. 1 with the light line describing the ratio of the graph before reduction and a bold line describing the ratio of the graph after reduction. The results showed that the ratios of Susceptible, Infected, and Removed had not much difference between the two graphs.

The second time, we used a random graph of 400 vertices, the probability to generate edges is 0.004, with 50 times the information was diffused. The results in Fig. 2 show the same result. The total time after performing 10 times for each experiment is shown in Table I.

The results from Fig. 1, 2, and Table I showed the effectiveness of the graph reduction method in speeding up the process of analyzing and diffusing information.

B. Paralleling the Betweenness Centrality Computation Process

First of all, to represent graphs there are three main methods: (1) edge list, (2) adjacent matrix, and (3) adjacent list. In a relatively large-scale graph, the edge-list method is quite simple, but the calculation on the graph such as inserting, deleting vertices is difficult. The adjacent matrix method is also not usable due to memory size limitations. Therefore, the most suitable is the adjacent list method. Thus, for vertice data, in the graph $G = (V, E)$, each vertice is assigned a value from 0 to $|V| - 1$. For edge data, vertice vectors are arranged to represent the edges of the graph, or edge data will be represented in the vector array.

Secondly, the BC computation by the method of Brandes depends largely on the BFS graph searching process. To reduce the size of the queue when searching, each time we search a vertex u, we will use the $Maps$ array where the v-th bit position represents the searching state or not of vertice v. The $Queue$ queue is also organized to store the shortest distance from u to the searched-vertice in the $Queue$. Due to the large size of the $Queue$ queue and searching bookmark $Maps$ array (with the number of elements equal to V), the memory allocation will take a lot of time. So we will preallocate the memory containing these arrays corresponding to the number of threads that can execute in parallel.

Thirdly, to be able to exploit the performance of multi-core CPUs, our plan to parallelize BC computation is to execute BC computations in parallel on different vertices, not parallelize the searching process and compute the shortest path from one vertice to all other vertices (SSSP). This approach allows SSSP searching to be performed in specialized threads, thereby improving cache access speed.

Fourthly, the libraries for parallelization, such as CilkPlus, OpenMP, and Pthread, Leist and Gilman in [5] experimented and demonstrated the CilkPlus library give a better speed-up factor than OpenMP and Pthread. Accordingly, we will use the Cilkplus library to install the parallel computation.

Finally, it can be said that computing on the graph with a large number of vertices and edges, in which the BC is a relatively difficult problem in parallel. The reason is that in Phase 2 of the algorithm, the accumulation process requires a simultaneous control technique to process the accumulated data from parallel threads. During research and testing, we added a $reducerBC[v]$ vector in the Cilkplus library [16]. Technically, $reducer$ allows creating a separate cumulative variable for each thread, and combining its own cumulative variable will result in the correct order when the threads end. That is $reducerBC[v]$ vector allows to update the BC value of vertice v when executed in parallel with the Cilkplus library.

From there, the algorithm to compute BC in parallel has been given in [21] and shown in Algorithm 2.

As can be seen, the time complexity of algorithm 1 is $O(|V|*|E|)$ and algorithm 2 is $O(\frac{(|V|*|E|)}{t})$. So with algorithm 2, if deployed algorithm with a thread $t = 1$, it would equal the complexity of Brandes' base algorithm of $O(|V| * |E|)$. However, if this algorithm is executed in parallel with t threads, the time complexity of the algorithm will be reduced by t times.

Algorithm 2: Computation of BC in parallel

Input: $G = (V, E)$ have been reduced, is organized as $Edges[][]$ vector field
Data: queue $Q \leftarrow$, stack S create the hollow (empty) and its able to contain $|V|$ vertices ;
$dist[v]$: to save the distance from the source vertice to v ;
$Pred[v]$: to store the list all the vertices on the shortest path from the source vertice to v ;
$\sigma[v]$: the number of shortest paths from the source vertice to v ;
$\delta[v]$: the number of shortest paths from the source vertice through v ;
$reducerBC[v]$: vector contains BC values of all vertices v and allows the concurrency update in parallel with CilkPlus library;
Output: $BC[.]$ for any $v \in V$

```
/* Execute in parallel using CilkPlus library */
for s = 0 to Edges.size() do
    /* Phase 2. Graph researching */
    foreach v ∈ V do Pred[v] ← empty list;
     dist[v] ← ∞; σ[v] ← 0 ;
    dist[s] ← 0; σ[s] ← 1; Q.push(s) ;
    while Q not empty do
        v ← Q.pop(); S.push(v) ;
        foreach w ∈ Edges[v] do
            if dist[w] == ∞ then
              dist[w] ← dist[v] + 1; Q.push(w) ;
            if dist[w] == dist[v] + 1 then σ[w] ←
              σ[w] + σ[v]; Pred[w].push_back(v);
        end
    end
    /* Phase 3. Accumulation */
    foreach v ∈ V do δ[v] ← 0;
    while S not empty do
        w ← S.pop() ;
        for v ∈ Pred[w] do
          δ[v] ← δ[v] + σ[v]/σ[w].(1 + δ[w]);
        if w ≠ s then
          reducerBC[w] ← reducerBC[w] + δ[w];
    end
end
reducerBC.move_out(BC) ;    /* to return
 the results to vector BC */
return BC[.] ;
```

C. Red-Bet Hybrid Method

The proposal RED-BET hybrid method is based on both the graph reduction and paralleling the BC computation process. First of all, the graph reduction is performed before the BFS phase in order to reduce both the vertices and the edges of graph. After that the BC computation process is executed to find the most important vertices in the social network. However, to consolidate the information diffusion, we have to prove the two mentioned contents above that the vertices that we replace are not important, their removal does not affect the graph too much and the "most important" property of those vertices is preserved.

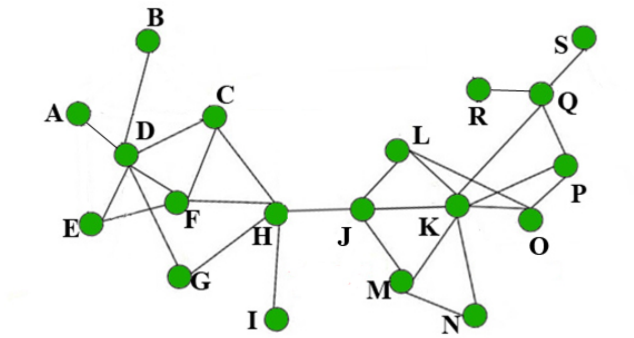

Fig. 3. Graph Before Reducing.

TABLE II. RESULT OF COMPUTING BC AND CC BEFORE REDUCING

Vertice	BC	CC	Vertice	BC	CC	Vertice	BC	CC
A	0	0.24	H	176	0.44	O	1	0.31
B	0	0.24	I	0	0.31	P	3	0.32
C	24	0.36	J	163	0.45	Q	66	0.33
D	71	0.31	K	133	0.42	R	0	0.25
E	0	0.29	L	10	0.37	S	0	0.25
F	49	0.37	M	10	0.37			
G	24	0.35	N	0	0.31			

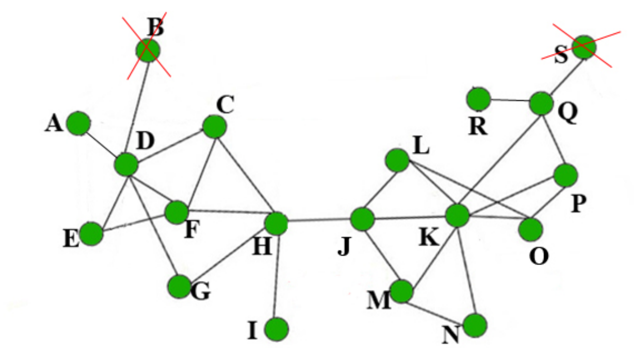

Fig. 4. Graph After Reducing.

To prove that we experiment on a simple graph with 19 vertices, 28 edges as shown in Fig. 3. Applying the formula to calculate the BC and the Closeness Centrality (CC), we get the results as Table II.

Thus, H is the vertice with the highest Betweenness Centrality $BC[H] = 176$ (then to the vertices J and K), J is the vertice with the highest Closeness Centrality $CC[J] = 0.45$ (after to the vertices H and K). With a simple small graph, intuitively we can see that vertices A and B are 2 equivalent 1-degree vertices, similarly vertices R and S are 2 equivalent 1-degree vertices. Apply the proposed graph reduction method, we obtain the graph after reduction as in Fig. 4.

Applying the formula for calculating the BC and CC with the graph after reduced, we get the results as Table III. After reduction, H is still the vertice with the highest Betweenness Centrality $BC[H] = 140$ (then to the vertices J and K), J is also the vertice with the highest Closeness Centrality $CC[J] = 0.48$ (then to the vertices H and K). Thus, it can be concluded that graph reduction by the proposed method, although changing the centrality value, does not affect the properties and important vertices of the graph for the diffusion information analysis problem.

TABLE III. RESULT OF COMPUTING BC AND CC AFTER REDUCING

Vertice	BC	CC	Vertice	BC	CC	Vertice	BC	CC
A	0	0.24	H	140	0.47	O	1	0.33
B	-	-	I	0	0.33	P	2	0.33
C	14.67	0.37	J	129	0.48	Q	30	0.33
D	35	0.31	K	98	0.44	R	0	0.25
E	0	0.30	L	9	0.39	S	-	-
F	37.67	0.38	M	9	0.39			
G	14.67	0.36	N	0	0.32			

For validating this method, we will conduct experiments in the next section to prove that: (1) the reduction brings more efficiency in parallelization than the non-reduction, that is, the experimental results of this research's algorithm are more optimal than the bigGraph algorithm [21]; (2) the speed-up factor of the proposed algorithm compared to the two tools NetworKit and TeexGraph is clearer than the speed-up factor of bigGraph algorithm when compared to the two tools NetworKit and TeexGraph.

IV. EXPERIMENT AND EVALUATION

To evaluate the effectiveness of the hybrid method in accelerating the BC calculation, we installed our algorithm on the computer with 2 x CPU (2-cores per CPU) configuration, 128 GB main memory, operating system CentOS Linux release 7.4.1708, gcc 7.2.0 compiler. This computing system was configured with a maximum of 36-threads in parallel.

A. Datasets

To test the above algorithm, we have collected social network data sets published from two major organizations, SNAP [10] and Aminer Datasets for Social Network Analysis [37] including:

- *ego-Facebook*: A data set built from Facebook's friends' lists. These lists are gathered from members participating in the Facebook application-based survey (DS1).

- *gemsec-Facebook*: A data set consisting of 8 subnets built to represent legitimate Facebook pages. These Facebook pages are modelled with vertices and edges representing the links between those pages. Due to the size and time limitations, we only selected two large networks in the gemsec-Facebook dataset for testing: Politician (DS2) and Artist (DS3).

- *com-DBLP*: This is a dataset that represents the DBLP co-authorship network (DS4).

- *com-Youtube*: This dataset is collected from the ground-truth communities in Youtube social network (DS5).

The above data sets are all connected graphs, their main characteristics are illustrated in Table IV.

TABLE IV. Experiment Dataset Characteristics

Dataset	Edges	Nodes	Diameter
ego-Facebook (DS1)	88,234	4,039	8
gemsec-Facebook Politician (DS2)	41,729	5,908	14
gemsec-Facebook Artist (DS3)	819,306	50,515	11
DBLP (DS4)	1,049,866	425,957	23
Youtube (DS5)	2,987,624	1,157,828	24

TABLE V. Execution Time (Seconds) to Compute BC

Threads	DS1		DS2		DS3	
	bigGraph	RED-BET	bigGraph	RED-BET	bigGraph	RED-BET
1	3.03	2.85	8.20	7.74	1129.47	1065.53
4	1.51	1.42	4.52	4.25	556.46	524.98
16	0.54	0.51	1.60	1.51	196.46	185.34
36	0.23	0.22	0.74	0.70	99.85	94.201

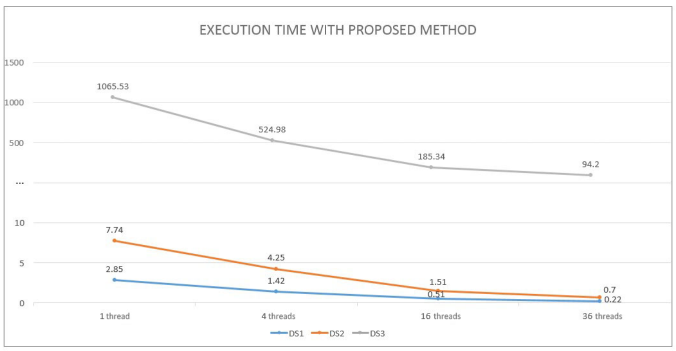

Fig. 5. Execution Time (Seconds) to Calculate BC of RED-BET.

B. Results and Evaluation

It should be noted, our previous research results in [21] have proven that executing more parallel threads will increase the speed up (i.e. time to compute BC less). Therefore, in this study, we do not re-prove the above content and only focus on proving two contents as mentioned in Part II, that is: (1) the reduction method brings more parallelization effect than the non-reduction, it means that the experimental results of this study (RED-BET) are more optimal than the bigGraph algorithm in the study [21]; (2) the speed-up factor of RED-BET compared to the two tools NetworKit and TeexGraph is clearer than the speed-up factor of bigGraph algorithm when compared to the two tools NetworKit and TeexGraph.

First, we tested the RED-BET algorithm and bigGraph algorithm with three datasets DS1, DS2, DS3 with 4 circumstances 1, 4, 16, 36 parallel threads. The aggregated results were based on the average execution time after 10 test runs for each solution and presented in Table V.

The result above shows that the proposed algorithm RED-BET combines graph reduction and parallelization have a smaller execution time, ie better performance than the bigGraph algorithm in previous studies [21]. To visualize, Fig. 5 shows the change of BC computation time with RED-BET algorithm when the number of parallel threads changes similar to the bigGraph algorithm.

Obviously, combined with the research [21], the proposed

TABLE VI. Time to Compute BC (Seconds)

Datasets	RED-BET	bigGraph	TeexGraph	NetworKit
DS1	0.22	0.23	0.31	0.56
DS2	0.70	0.74	0.84	1.70
DS3	94.20	99.85	110.58	234.12
DS4	2193.54	2345.62	2694.78	4823.47
DS5	50977.15	56071.60	68744.80	90522.30

TABLE VII. Speed up Factor of RED-BET Compared with BigGraph, TeexGraph and NetworKit when Computing BC

Datasets	RED-BET / bigGraph	RED-BET / TeexGraph	RED-BET / NetworKit
DS1	1.05	1.41	2.55
DS2	1.06	1.2	2.43
DS3	1.06	1.17	2.49
DS4	1.07	1.23	2.2
DS5	1.15	1.35	1.76

algorithm RED-BET would also be more efficient than the NetworKit and TeexGraph toolkits. However, to be objective in research, we continue to test the RED-BET algorithm with two datasets DS4, DS5 to compare and evaluate the speed-up factor compared to NetworKit and TeexGraph. In all tests, we used 36 parallel threads (the maximum number of threads on the system). Table VI illustrates the average time of 10 executions of the BC center calculation of the four solutions in the test.

Detailed representation of the time to compute the BC of four solutions is illustrated in Fig. 4. Table V and Fig. 6 confirmed that the RED-BET algorithm has a smaller execution time than the TeexGraph and NetworKit toolkits. The speed up factor of the proposed algorithm compared to the bigGraph algorithm and the two tools TeexGraph and NetworKit are shown in Table VI.

Thus, for all three datasets, the RED-BET algorithm gives better performance, computing the BC in the shortest time compared to the tools TeexGraph, NetworKit as well as bigGraph algorithm in the previous study. Table VII also shows the speed-up factor of RED-BET is clearer when compared to TeexGraph, NetworKit, 1.2 to 1.41 times when compared to TeexGraph and 1.76 to 2.55 times when compared to NetworKit.

V. Conclusion

In this paper, we focus on accelerating the computation in information diffusion on the social network. The proposed RED-BET method is based on both the graph reduction and the parallelization of BC computation. Specifically, it combines the process of reducing the graph based on replacing the equivalent 1-degree vertices and parallelizing the SSSP calculations in Brandes' algorithm with the parallel thread programming model on the CPU and using the CilkPlus library. The time complexity of the proposed algorithm is $O(\frac{(|V|*|E|)}{t})$, where t is the number of parallel threads.

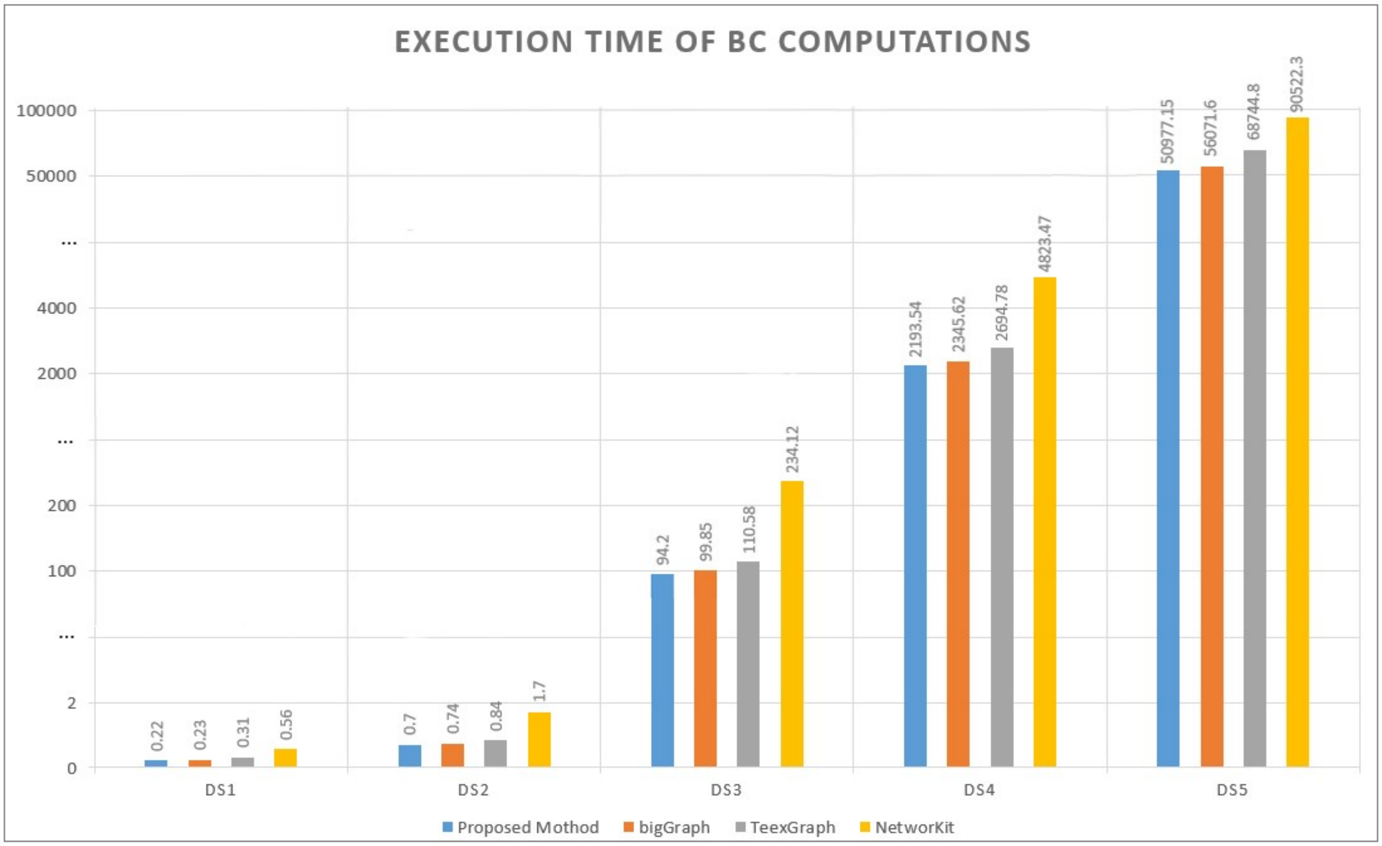

Fig. 6. Evaluation of BC Execution Time for Different Solutions (Seconds).

Our RED-BET algorithm was tested with some datasets published from two major organizations, SNAP and Aminer. Test results show that our solution is more efficient 1.2 to 1.41 times than the TeexGraph toolkit, 1.76 to 2.55 times than the NetworKit toolkit, and 1.05 to 1.1 times than the bigGraph.

In future work, we will focus on expanding our method to accelerate the calculation of other metrics in information diffusion analysis on the social network.

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A Comprehensive Study on Intrusion and Extrusion Phenomena

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***Abstract*—This paper presents a comprehensive survey on intrusion and extrusion phenomena and their existing detection and prevention techniques. Intrusion and extrusion events, breach of security system, hamper the protection of the devices or systems. Needless to say that security threats are flourishing with new level of complexity making difficulty in recognizing them. Therefore, security is the remarkable issue at the core of developing a boundless, constant and reliable web. In this paper, our purpose is to unveil and categorize all possible intrusion and extrusion events, bring out issues related to events and explore solutions associated with them. Nevertheless, we suggest further recommendations to improve the security in these issues. We strongly believe that this survey may help understanding intrusion and extrusion phenomena, and pave the way for a better design to protect against security threats.**

***Keywords*—Intrusion; extrusion; intrusion detection; security and survey**

I. Introduction

No doubt, computing technology has changed the lifestyle of people drastically. All of these are happening through connecting devices, we call it networks. As devices are getting smarter and knowledgeable, people became much more dependent towards these devices. Things that come with comfort and contentment also brings issues and worries with it.

As networks are assisting individuals to communicate through the connecting devices, threats and breaches are getting more prominent. Computer security is the protection of electronic data and information against inner and outer, malevolent and vulnerability threats [1]. It renders protection as well as prevention from attacks and keeps the information secure. However, due to growth of the new technologies along with sophisticate devices, types and nature of the attacks are also changing [2].

All probable occurrences, contraventions, or approaching threats that violate system security are known as intrusion and extrusion events. More precisely, if an insider or outsider potentially intrudes the local system with his own remote system, it is known as intrusion event. Extrusion, known as an attack event, that generates from the local host system to take control over the system. It is usually done by the insider who is authorized to use any devices of the organization. To shield devices and networks against intrusion or extrusion events, security must be enough savvy and intelligent [3]. The concept of network security was first initiated in the late 1980s and since then experts have been exhorted to the unpredictable risk of numerous unsecured interconnected devices to the internet [4]. Now a days, numerous attacks events relate to intrusion and extrusion are continuously increasing concerns, devices like computer, refrigerators and even TVs are being used to dispatch malicious things to hackers. Hackers usually do not attack the devices themselves, but instead use other malicious devices to break into [5].

Some remarkable attack events related to intrusion and extrusion that affected the world most are RFIT botnet (December, 2018), ThinkPHP exploitation (11 December, 2018), D-link router exploitation, Shaolin botnet (exploitation of NETGEAR vulnerability, January, 2019), Mirai botnet [6][7], the botnet barrage, Notpetya ransomware attack (June, 2017), etc. Most of these attacks are not discussed and also not prevented even though systems have enough security. So, it is hard to accept that even after 28-years, system does not have enough security to detect or prevent such events. Without these exception, devices and systems also face some regular intrusion and extrusion attacks, such as Address resolution protocol attack, Internet Control Message Protocol (ICMP) attack, Fraggle attack, ICMP tunneling attack, Internet Protocol (IP) fragment attack, Malformed packet, Outbound raw attack, Ping-of-death attack, Distributed denial of services, Phishing, Supply chain attack, Router attack etc, to name a few.

Although the conventional solutions exist on the aforementioned attacks, still the occurrence of the mentioned remarkable events indicate that no systems are fully protected. We have explored a large number of surveys on attacks. Some surveys [8][9][10][11] discussed about the attacks in different layers . Some [12][13][14] have only discussed about DDoS attacks. Some [15][16][17] surveys mainly focused on intrusion detection and prevention systems. As network is expanding its region, more intrusion and extrusion events are occurring which are never discussed before.

This article incorporates up-to-date taxonomy, as well as descriptions of important scientific work in the field of incursion and extrusion. It offers an overview of the current intrusion and extrusion detection system in an organized and thorough fashion so that interested academics may rapidly learn about essential areas of anomaly detection. The intricacy and implications of the various approaches and their assessment procedures will be explored.

There have been no papers that thoroughly cover infiltration and extrusion detection, outcomes, and various types of attacks. Furthermore, the advancement of intrusion-detection systems has resulted in the proposal of numerous distinct systems in the interim. This document provides up-to-date information on the subject.

We have presented a comprehensive and in depth study on intrusion and extrusion events. Mostly, extrusion attacks [18] and their detection systems [19] are not covered in existing surveys. For better understanding, we have discussed about attacks' real-life examples, constructive definitions, attacks' consequences, their complexities, limitations and merits, method comparison and efficiency, etc.

As time passes, a scenario with a relatively novel phenomena emerges, and network defenses are inadequate. Because of the ubiquity of computer networks and our ever-increasing reliance on them, becoming aware of the threat might have disastrous repercussions. The density of study on this topic is continually increasing, and more scholars are becoming involved in this field of work on a daily basis. The potential of a new wave of cyber or network assaults is not just a possibility to be considered; it is a known truth that can occur at any time. We think that study should not be restricted to the concerns raised in this work.

Nevertheless, most of these events have never been categorized for understanding of the problems. In our paper, we categorize the attacks on the basis of intrusion and extrusion and we provide a comprehensive discussion on those events for better understanding. We further relate those events in terms of TCP/IP layers. All these motivated us in writing this article. We firmly believe that our effort might convey indelible influence to the research community towards next level of perfection.

The rest of the of paper is organized as follows. Section 2 outlines the taxonomy of intrusion and extrusion events. The intrusion events are described in details in Section 3. Section 4 continues with the detailed description on extrusion events. We present a big picture in tabular form summarizing all the intrusion and extrusion events in Section 5. Finally, We present open challenges and future research Issues in Section 6 and at end, we conclude our research in Section 7.

II. Taxonomy of Intrusion and Extrusion

This paper categorizes different attacks into intrusion and extrusion events. Nevertheless, each of the attack is associated with any of the layers in TCP/IP protocol suite. Hence, our main classification also exhibits the corresponding layer where the attack occurs as demonstrated in Fig. 1. We have enlisted 14 intrusion and 10 extrusion events knowing that this list will grow in course of time. AS far as our knowledge perceives, this is the first attempt that accumulates all the intrusion and extrusion events, along with their comparative analyses.

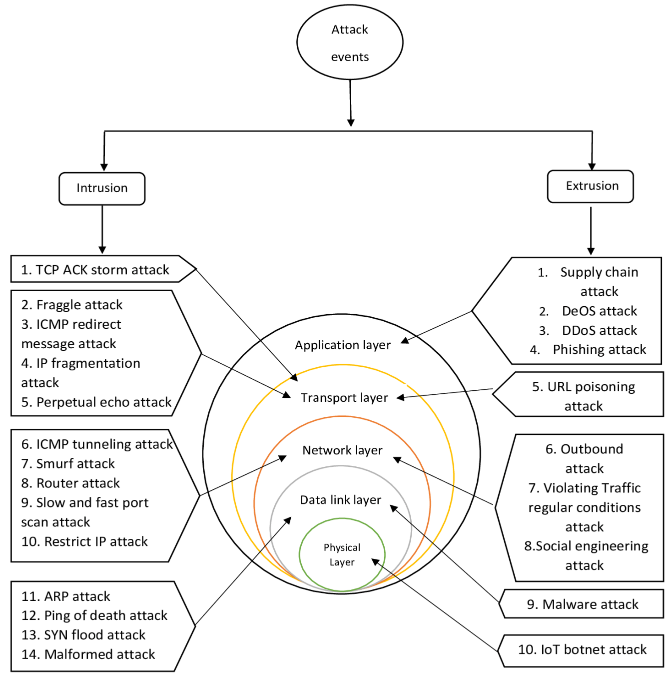

Fig. 1. An Overall Taxonomy of Intrusion and Extrusion Events.

III. Intrusion Events

This body of our work digs out the intrusion events manifesting their definitions, explaining how they occur and presenting the possible solutions for them along with figures wherever applicable. When a trusted insider violates the regular use of the system, then an intrusion event occur. The most common intruders may be the hackers, company's employees, criminal enterprises etc. Any attack that roots from a remote system to a local system is considered to be intrusion. Suppose, an attacker disguises himself as a legitimate host and sends request (i.e. malware, malformed packets, emails, etc.) to the targeted PC. If an authorized user accepts the request, the malware or malformed packets might attack or freeze his PC or this request might lead him to a proxy fake website and force him to fill the personal information. Thus, the information will be revealed to the attacker. This process is known as intrusion event. Fig. 2 illustrates a generalized model of how intrusion event occurs.

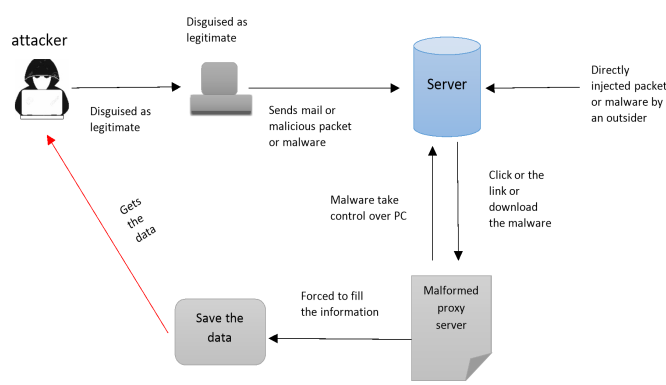

Fig. 2. A Generalized Model Depicting the Occurrence of an Intrusion Event.

A. *TCP-ACK Storm Attack*

This particular attack occurs over TLS/SSL connections along with TCP connections that remain unprotected. However, system having IPsec or link-layer encrypted connections is protective against this attack [20].

It is launched by a man in the middle attacker who only eavesdrops when needed and creates malicious packets. Theoretically, this attack[21] might spread in a limitless manner . The worst case can be N-packets of ACK-storm DoS attack may consume the overall bandwidth of a network. When a receiver receives an unacceptable packet from the attacker, the host acknowledges the packet and sends the expected sequence number to the attacker by using its own sequence number. In most cases, an attacker receives a packet with receiver's sequence number larger than the one sent by a receiving client with the standard TCP connection. Even though, this packet is unacceptable, it generates an acknowledgment packet. This generated packet eventually generates other acknowledgment packets causing unlimited loops for each data packet. Whenever the ACK packet [22] is lost, it will not be retransmitted since it contains no meaningful data. ACK storm is less if the network drops more packets.

The Mitnick case (1994): A disguised attacker verily hacked the computers in the San Diego Supercomputer Center. This was happened to be the most secure computer system in US [23]. The financial services industry also experienced same type of attack. In March 2019, the attack was so sophisticated which was not previously seen before. Though it has an easy fix by tuning TCP or using a packet-filtering firewall system.

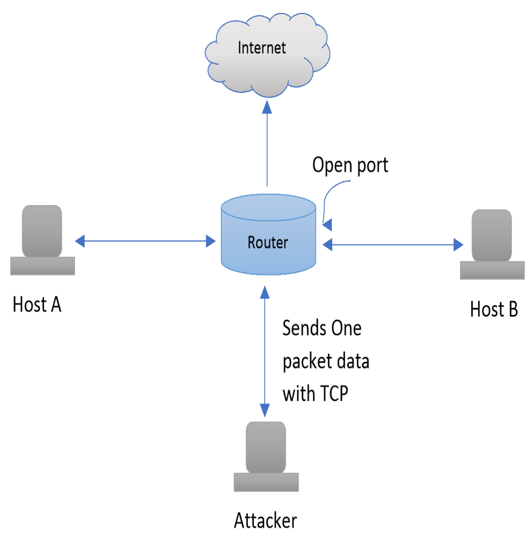

Fig. 3. TCP-ACK Storm: Attacker Changes One Network Packet with Malicious Packet.

Fig. 3 depicts the procedure of TCP-ACK storm with one packet that consists of three processes:

1) Attacker picks up a packet from connected network among host A and host B as there is an open port exist in the router.
2) Then, attacker generates one packet which will address to host A and sends with host A's address to host B. Packet must have at least one byte of data. Packet must be inside the TCP connection.
3) Finally, hacker manages to send packets form Host A to Host B maintaining the time frame. As the attackers gets reply, it will continue in a loop of back and forth of packets.

The basic one packet TCP-ACK storm attack [24] can be further amplified to the Two-packets Ack-Storm attack, exhausting bandwidth and lengthening the session duration. This attack causes disruption of the regular web activities by sending huge traffic.

Some existing solutions related to this attack are shown in Table I.

B. *Fraggle Attack*

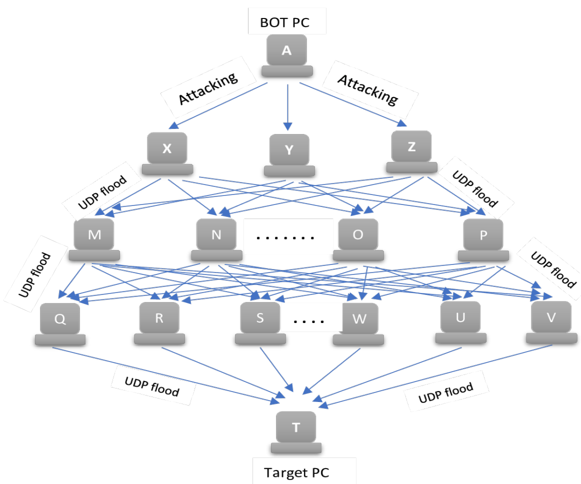

Fig. 4. An Example of Fraggle Attack.

Fig. 4, attacker is attacking the computers using BOT PC A to generate UDP flood to PC X, Y and Z. This UDP flood is then propagated to the nodes downward. Note that, port 7 is open for all computers and it supports character generation system. Eventually, the traffic will overwhelm the target PC T and block its normal functioning, resulting in fraggle attack.

The Fraggle attack is a type of amplification attack where UDP packets are dispatched to ports 7 and 19 depending on which one is open. Also, character generation service may run which is eligible for character generation. This intrusion may cause havoc to the system with the help of the insiders as they unintentionally help the hackers to flood UDP packets. As this attack is not new, all operating systems are protected from such attack. Therefore, no new such attacks[28] have been found nowadays, although in the late 90s, the attack was very acute.

A successful attempt of Fraggle attack may hang any system servers for an indefinite period of time (e.g., hours, days or even months). To Identify Fraggle attack, three types of techniques are introduced: traffic degree monitoring, source IP address monitoring, and packet attributes analysis. When the attack is detected, some countermeasures might be taken such as filtration [29], congestion control [30], Submissive trace back [31], Reproduction [32], etc.

TABLE I. STATE-OF-THE-ART SOLUTIONS OF TCP-ACK STORM

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Raz et al 2011[25]	Modifying the TCP	✗	✓	Hassle-some for the network architecture.	Generated everlasting TCP amplification	only 1% packet loss	Yes	Yes
Neminath et al 2018 [22]	State transition model	✓	✗	Snatches TCP's capability to re-synchronising the sequence numbers	Real experiment of attack and detection in test bed setup	Close to 100%	Yes	Yes
Duc et al 2019 [26]	Hypervisor at close state	✓	✗	Analyzed TCP ACK Storm DoS attack against virtual network systems	Defining the packet size every-time is hard for the system	Takes 60sec to detect	No	No
Topalova et al 2019 [27]	MLPNN structure	✓	✗	It doesn't have prevention method	Analysis of automated system based on Multi layer neural network	Approximately 75%	Yes	Yes

C. An ICMP Redirect Message Attack

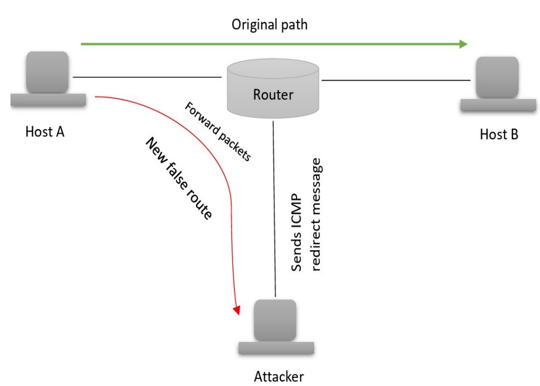

Fig. 5. ICMP Redirect Message Attack: Attackers Manipulating ICMP Messages between Server and Client's PC.

ICMP redirect message sends out of bound message that passes the information to a host regarding the existence of more optimal routes through the server network. But this system is effectively misused by the attacker to redirect the traffic or information to his own system. In this attack, the hacker poisons the router by sending ICMP redirect message to the targeted host, so that all traffic uses optimal way for the destination. These attacks mostly happen on the port or network layer. These attacks can also cause problems if there exists firewall and non-deterministic traffic [33]. Zimperium Mobile Security Labs have researched last year attack named “DoubleDirect” which can be generated through ICMP redirect massage attack. It enables the attacker to redirect target's traffic [34] to attacker's PC. Once the process is done, attacker may steal or inject payload to the victim's PC. Machine learning approach generates the best detection rate till now.

In Fig. 5, host A is the source and host B is the destination. The files are supposed to transfer from source to destination through router. But the attacker redirects the messages by manipulating the router. Hence, the files finds the new path and goes to the attacker's PC considering it as the destination. In what follows, the Table II enlists some existing solutions to this attacks.

D. Internet Protocol (IP) Fragmentation Attack

IP fragmentation attack exploits the IP fragmentation mechanism as an attack vector [40] [41].

Black nurse attack is one of the most common organizational names of IP fragmentation attack. Basically, it is based on sending crafted IP fragments in order to eliminate firewall services [42].

This process may occur in two ways as described in the following:

1) UDP and ICMP fragmentation attacks: This attack [43] exploits the transmission of malicious UDP or ICMP packets exceeding the maximum transmission unit. The inability of reassembling these packets causes high resource consumption resulting in the victim server issues.
2) TCP fragmentation attacks: This attack, also regarded Teardrop attack, inhibits reassembly procedure of the TCP/IP for the fragmented data packets resulting in data packets overlap. Consequently, the server gets swamped [44].

Improving packet loss and 95% accuracy rate makes sparsely tagged fragmentation marking a best solution for this attack. Table III presents existing solutions related to this attack.

E. Perpetual Echo Attack

Perpetual echo attack [51], a fraudulent activity, takes place at port 7. Source port and the destination port perpetually echo each other when the connection is established . UDP requests are sent to a malicious IP address for all victims to get back their responses. The malicious source address is not the

TABLE II. State-of-the-Art Solutions of an ICMP Redirect Message Attack

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Prerna et al. 2015 [35]	Centralized system	✗	✓	If Central server is unable to find correct match, it needs to send broadcast request. Time complexity increases	Analyze ICMP and Voting with Backward Compatibility, Less Cost, Minimal Traffic and Easily deployed	complexity O(logN)	Yes	Yes
Jaspreet et al. 2017 [36]	Signature based machine learning tool	✓	✗	Low accuracy rate	Application of machine learning tools	93% accuracy	No	No
Dalal et al. 2018 [33]	PrECast proxy service	✗	✓	No solution for DNS amplification originated from an external network towards a host inside a LAN	Cryto free solution without modification of protocol	complexity and convergence time can take upto 200 massages	Yes	Yes but some modification required.
Ahmed et al. 2018 [37]	AR-match technique	✗	✓	Weak hash function algorithm for high-security purpose	solving High complexity using Ar-match technique	Not mentioned	Yes	Yes
Viegas et al. 2019[38]	BigFlow	✓	✗	Only Worked on limited bandwidth	Analyze the behavior of several traditional ML classifiers	Accuracy approximately 90%	Yes	Yes
Jonas et al. 2019[39]	Open Flow	✗	✓	There is no rate limiting of the Virtual machine when sending to much traffic into the network	improvement of security of libvirt virtual machines connect via an Open vSwitch	Not mentioned	No	No

attacker's correct address. Hence, the hacker remains disguised and the targeted user becomes the victim of large traffic. This may lead to DoS attacks [52] on the UDP ports. Some UDP applications unconditionally respond to every datagram received. If a datagram is inserted into the network with one of these applications as the destination and another of these applications spoofed as the source, the two applications will respond to each other continually. Each inserted datagram will result in another perpetual echo conversation between them. In the worst case, attacker's attempt is to hide attacks or render them and become untraceable. Ant colony optimization has more efficiency to generate true alarm rate while detecting the attack

In Fig. 6, attacker uses another PC's IP address to remain hidden and sends UDP flood through port 7 of the router to the target PC to establish connection. If one connection is established, the affected PC will be working as BOT that sends UDP flood to other PC. Table IV presents existing solutions to this attack.

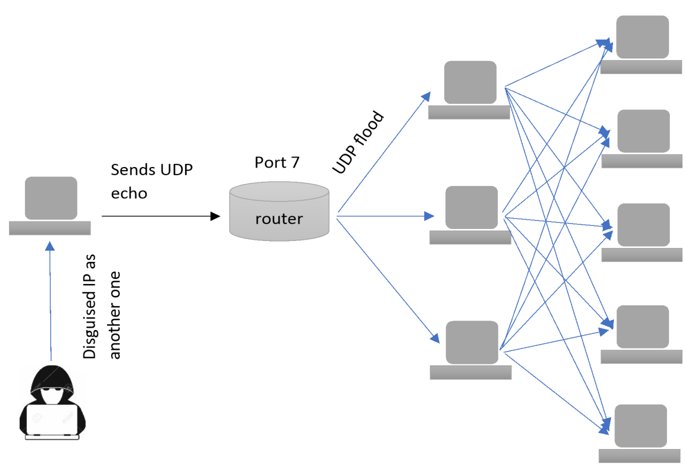

Fig. 6. Echo on user Datagram Protocol (UDP) Ports: Source Port Perpetuals Echo to All Target Ports Modified by Attacker.

F. Internet Control Message Protocol (ICMP) Tunneling Attack

ICMP tunnel is created where the information flow may not be regulated by security technique. ICMP is used as an attack vector shield of IP-Sec gateway [55]. In the worst case, attackers are able to disturb the network design architecture by doing malicious activity. An ICMP tunneling attack makes connection between the hosts, and ruins the firewall service in a way that it fails to alarm if any data sent via ICMP. It is a covert connection [56] between hosts using ICMP messages

TABLE III. STATE-OF-THE-ART SOLUTIONS OF INTERNET PROTOCOL(IP) FRAGMENTATION ATTACK

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Bernstein et al 2012 [45]	Edwards-curve Digital Signature Algorithm	✗	✓	It is not a benchmark framework	Strong defenses against software side-channel attack	Drastically reducing the number of branches	Yes	No
Hasmukh et al 2018 [46]	Sparsely-Tagged Fragmentation Marking approach	✓	✓	Authentication of the marking at victim is needed to prevent compromise routers to spoof the marking	Improves the Probabilistic packet marketing by reducing the number of packets	95% accuracy	Yes	Yes
Mahmud et al. 2018[47]	SecuPAN proposed tool	✓	✓	Mitigates the attack	verify authenticity and integrity	Completion time 35ms	Yes	No
Chaoqin et al. 2018 [48]	Integrated IP Source Address Validation Architecture (ISAVA)	✓	✓	Filtering rate is not 100 percent accurate	Maximizes the SDN control pattern	Transfer time 8s	Yes	Yes
Bakker et al 2019[49]	BGP Flowspec rules	✓	✗	It can not be used as the only way of defense	Specify rules on traffic and it's limitations	effectiveness is higher than Impact	Yes	No
Al-Ani et al 2019[50]	New mechanism against attacks	✓	✗	Can not block all kinds of packets	It can evade the OpenFlow firewall	Not mentioned	Yes	No

TABLE IV. STATE-OF-THE-ART SOLUTIONS OF PERPETUAL ECHO ATTACK

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Gupta et al 2014[53]	Ant Colony Optimization	✓	✗	The performance of the model considerably varies on a larger and more congested network	real life experiment and implementation	better detection rates and reduced false alarm rates	Yes	Yes
Okeke et al 2016[54]	Prey Predator (PP) approach	✓	✗	Many issues like manifesting and buffer overflow exists	Described the application of Prey Predator approach	Not mentioned	No	No

and reply packets. It can be done by changing the payload data so that it contains the attacker's data. So, if anyone uses ICMP messages, he may easily inject malicious data to be destined to the targeted PC. The targeted PC also replies into another ICMP message and returns it back.

In Fig. 7, host A is using an original server through a proxy server. Proxy server may be easily manipulated or authorized by the attacker without the knowledge of the firewall. ICMP messages are used as the payload in this figure. Thus, the information is routed through the attacker's PC without anyone's interference or knowledge.

G. Smurf Attack

Smurf attack mostly resembles to ping flood attack due to their similar nature of sending ICMP echo request packets. It, being an amplification attack vector [57], accelerates its damage potential through utilizing broadcast network characteristics. It is different than ping flood.

1990 is the year when first smurf attack [58] happened in University of Minnesota. It has effected more than 1 hour and chaining throughout the state. It has completely shut down many computers and servers. As a result, we face loss of

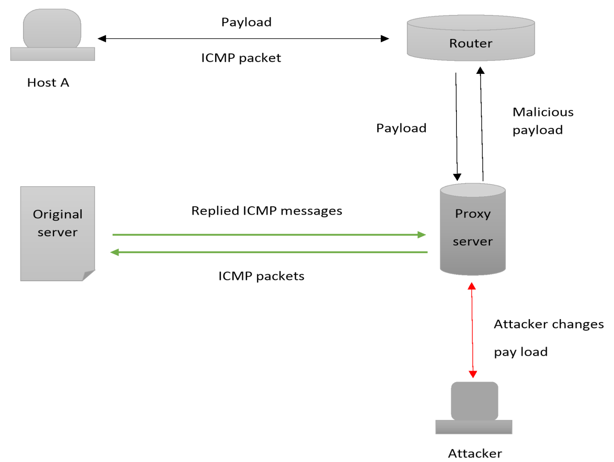

Fig. 7. ICMP Tunneling: Attackers Manipulating ICMP Payload to the Host A and Receiving Desired Packets.

data and slowdowns. We need to IP broad casting to eliminate Smurf attack.

Following describes the procedure of Smurf attack.

1) The malware generates a network packet attached to a fake IP address. There is a ping message inside the packet. Upon receiving these spoofed packets, the nodes echo back causing a loop eventually leading to a complete denial of service.
2) An insider may directly inject smurf Trojan or it may be accidentally downloaded from forged e-mail or web site. Typically it will remain as it is until activated by the attacker. Consequently, a good number of Smurfs are integrated with rootkits, allows hackers to create backdoor for system access.

Table V shows state-of-the-art solutions of smurf attack.

H. Router Attack

Router attacks mainly exploit the vulnerabilities in the networking protocols that lead to inconsistency in software and weak authentication [61]. It normally occurs in the network layer. Attacks [62][63], that can be a part or origin from router attacks, are mainly brute force and denial of service attacks. When it occurs, it impacts network services and business operations.

2018's report from eSentire shows 539% of increase in router attackers since 2017. ACI (American consumer institute) also found 84% WiFi routers [64] are under risk of cyber attacks or malicious activity. As, people are not aware of security vulnerabilities properly, hackers takes the chance. Black hole routers can detect most types of the router attack and can be modified if the attacker's way changes with time.

In Fig. 8, attacker modified the valid protocol to make new protocol which is malicious and may cause havoc to the system. Some attacks that might disrupt the performance of the router is discussed in the following.

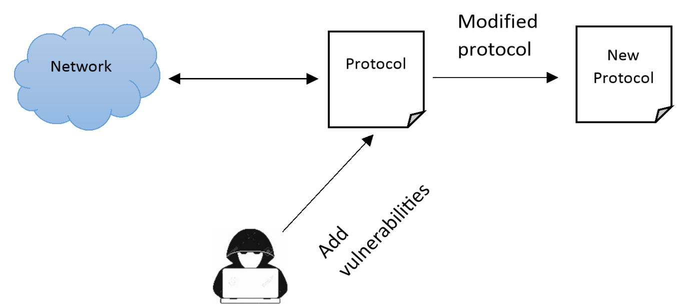

Fig. 8. Router Attack: Attacker Changed the Established Protocol with the Modified Protocol to Ensure Vulnerabilities in Network.

1) Brute Force: Brute force attack is a method where trial and error process is used to get data such as user's password or pin details. In this attack, an automated software generates a large number of close to accurate guesses as to get the desired value. It may be used by the attacker to crack the encrypted data. It may also be used to test the security system of any organization.

2) Packet Mistreating Attack: Router attacks may lead to packet mistreating, mostly like DoS attacks. These packets get mistreated by injecting malicious packets to confuse and overwhelm the system.

3) Routing Table Poisoning: A routing table in a router is not immune to protection and encryption vulnerabilities.Routing table may poison the whole routing routine. These attacks are achieved by manipulating the packet information that are routed through the router.

4) Hit and Run Attacks: This attack is also known as test hacks, and occurs when malicious data is injected into a router. However, the injection process may or may not be successful. The main aim of the is to disturb the environment of a system.

5) Persistent Attacks on Routers: Persistent attack is somewhat similar to hit and run, but in this attack, the injection process becomes successful and the attacker may gain control over the system. After injecting, it will continue it's intended work. The attacker will continue to add malicious packets and confuse the routing table thereafter.

Table VI depicts some existing solutions related to router attack.

I. Slow and Fast Port Scans Attack

Port scanning [67] is one of the dangerous network intrusions for getting exploitable communication channel between the attacker and the target. Attacker uses attack to discover service to get into the network. It consists of probing a host in a network for open host. It not only scans but also gathers information that attempts to profile the services running on a potential target. Port scan attack on 4G router of HUAWEI company [68], detected last year, is one of the recent port scan attack complained by the consumers. Artificial immune systems and fuzzy logic provide more accuracy and also have a robust model compared to other models.

In Fig. 9, attacker uses two scanners to send malicious requests disguised as service messages for scanning system

TABLE V. STATE-OF-THE-ART SOLUTIONS OF SMURF ATTACK

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Jayashree et al 2018 [59]	Pattern Matching Techniques	✓	✗	Accuracy is less than desired	Pattern matching technique for WSN	packet delivery ratio 1.3	Yes	No
Myo et al 2019 [57]	SDN based technique	✓	✗	Real time results are missing.	SDN and DDoS attack is discussed	average accuracy is 0.97	Yes	No
Trung et al 2019[60]	An enhanced History-based IP Filtering scheme	✓	✗	Lack of enhancement in the packet process	Described IP model for IP filtering	response time 60ms to 120 ms	Yes	No

TABLE VI. STATE-OF-THE-ART SOLUTIONS OF ROUTER ATTACK

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Ryoki et al 2016[65]	An Interest flow balancing method	✓	✓	The router does not record information for further use	Described countermeasures of IFA	Not mentioned	No	No
Yufeng et al 2018[21]	Distributed router shadow	✓	✗	The connection between router shadow and real router creates real difficulties	Structure and process of router shadow	minimum latency and intended load reduce	No	Yes
Dauod et al 2019[66]	HT-based threat model, known as Black Hole Router (BHR)	✓	✓	Increased the waiting time	Real life experiment of black hole method	10.83%, 27.78% and 21.31% overhead in area, power, and performance	Yes	Yes

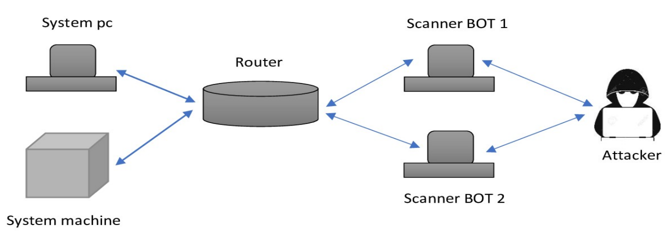

Fig. 9. Scan Attacks: Attackers use BOT Scanners to Scan Data from System's Machine.

devices. These scanners scan the system PC and machine and send results to the attacker.

These attacks are of two types, slow and fast port scan attacks.

1) Slow scan is an active scanning of devices[69] that connects to network where two successive probe messages are spaced in time at least in minutes, but mostly in hours or days. It may take weeks or even months to complete the process. As time passes by, network noise can destroy the scans which might remain unnoticed. Suspicion may be avoided through scanning target slowly by the attacker. Attackers send probe packets in every 5 or 15 minutes. Since slow scan does not create any deviation in the normal traffic, detection of this scan through anomaly and real time detection is very difficult[70].
2) An attacker scans the port in order to change the traffic settings. It can last for minutes or some fractions seconds.

Table VII shows some of the existing solutions of slow and fast port scan.

J. Restricted IP Attack

It allows an attacker to limit access [76] to the site to an attacker's defined set of IP addresses. If anyone attempts

TABLE VII. State-of-the-Art Solutions of Slow and Fast Port Scan Attack

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Mathieu et al 2018 [71]	Scan Chain Encryption	✓	✗	It is only applied on non-modifiable cores	secure and cost efficient mechanism	100% fault coverage	No	Yes
Markus et al 2018 [68]	Classification algorithm	✗	✓	It is not applied on real world network data.	problem setting and the underlying flow-based data are analyzed	Not sued any accuracy measurement	Yes	Yes
Manuel et al 2019 [72]	Time-aware metrics in NIDS evaluations	✓	✗	Application of time-aware machine learning models is missing	Used time-aware evaluation metrics for the early intrusion detection problem, identifying advantages and disadvantages	0.85 recall and precision	Yes	No
Mohammad et al 2019 [73]	Fuzzy Rule Interpolation	✓	✗	Prevention method is missing	Effectively detect the very slow and slow port scans based solely on the sparse fuzzy rules.	Not mentioned	No	No
Hartpence et al 2020 [74]	Sequential Neural Networks	✓	✗	No new algorithm is focused	sequential NN architecture	99% accuracy	No	No
GUSTAVO et al 2020 [75]	Artificial Immune Systems and Fuzzy Logic	✓	✗	Real network environment should be considered	Method comparisons are discussed with efficiency	99.9% accuracy	Yes	No

for site access from different IP address not belonging to the list of authorized IP addresses, it will be redirected to an access denied page. No blocks will be rendered, and no JavaScript will be added to the page. The module also has various configuration options including white list or blacklist pages, bypass IP checking by role, and alter the output when blocked. System administrator [77][78] uses this option for enforcing IP-based restrictions to minimize unwanted traffic.

Over 30%[79] of secure access cloud customers are using the IP address restriction to limit access to corporate resources from a specific set of IP addresses, while still performing strong user authentication.

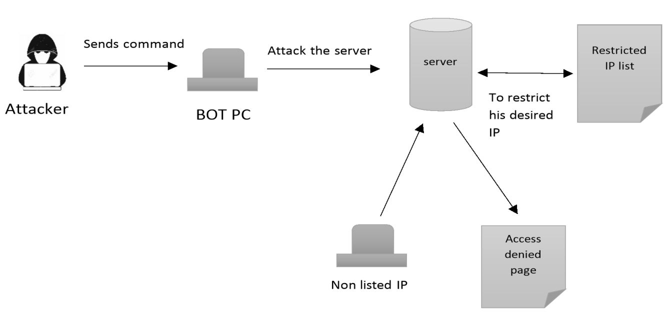

Fig. 10. Restricted IP Attack: Attacker Restricts the IP to Stop Valid users to Visit the Website.

In Fig. 10, attacker sends commands to the BOT PC to attack the main server in order to modify the restrict IP list, so that which PCs are in the restricted list may easily get access in the server.

Table VIII shows some of the existing solutions of the restrict IP option.

K. Address Resolution Protocol(ARP) Attack

Fig. 11 shows how ARP attack occurs. Let us assume, two hosts PC1 and PC2 are connected through a switch. An attacker, say PC3, is also connected in the same switch. It has modified the MAC address of other hosts with his own MAC address which is EE:EE:EE:FF:FF:FF. In such way, it may get the desired data that is being transferred between two hosts.

ARP spoofing is an attack that occurs when a hacker dispatches fake ARP messages to the local system network. It ends up connecting a hacker's media access control (MAC) address with the IP address of the device that existed in the network. Once the attacker is connected with the system device, he may get his desired information from that device by disguising his own identity. This attack enables attackers to intrude, edit or steal data from the system and also stops data from being transmitted between the system and the host [81].

In April 2018, Cisco Talos released information on the Sea Turtle campaign that hijacked and redirected traffic from more than 40 government and enterprise organizations using ARP

TABLE VIII. STATE-OF-THE-ART SOLUTIONS OF RESTRICTED IP OPTION

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Manju et al 2014[77]	SQL Injection detection mechanism	✓	✗	Not enough efficient to integrate in a system.	Detects more SQL injection vulnerabilities hidden behind the inadequate blacklist defense.	Detects all attack in the test case	Yes	No
Kim et al 2019[80]	ARP table update state-based detection approach	✓	✗	100 ARP replies is the limit. Attacker may do less reply to attack.	Analyzes SDN, SFC, and the vulnerabilities	Not mentioned	Yes	Yes

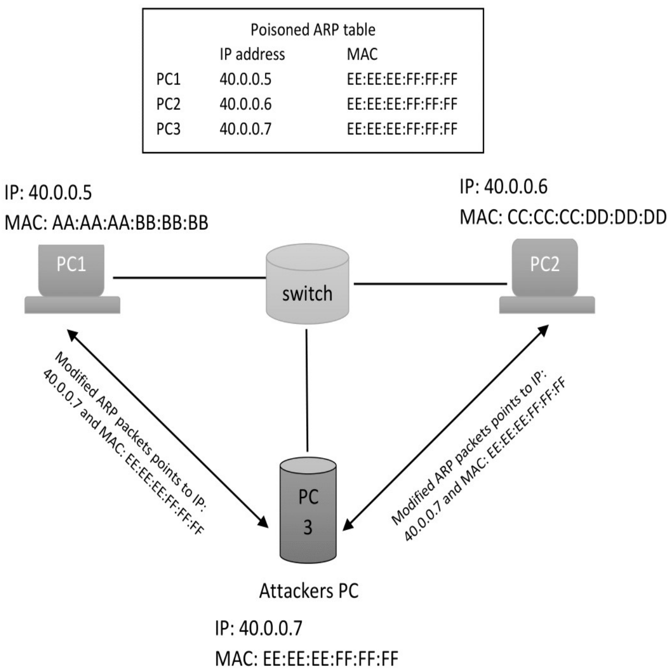

Fig. 11. Occurrence of ARP Attack: Attacker Manipulates ARP Table to Connect as Legitimate Server.

attack [82]. Match prevention is the best way to defend this attack as most ARP replies can be detected by this model.

ARP intrusion may result in the following types of attacks:

1) Session Hijacking: It is a cyber security attack on a user session over a network. In this attack, attackers exploit ARP spoofing attack to get one session ID and steal their sensitive information.

2) Man in the Middle Attack: This attack also employs ARP spoofing to disturb the traffic from a user and manipulates it to get access to user sessions. This attack re-routes the network traffic between the host and the attacker. So, the attacker will transmit the received packets to the desired destination. Hence, the communication between two original hosts is not disrupted and the sniffing process may go unnoticed.

3) Cloning Attack: In this attack, hacker himself change his IP and MAC to look exactly like the target host. Once the process is done, there will be two hosts having same address. The target host gets confused and the attacker takes the advantage as real one.

As ARP intrusion can have many forms, detection can be difficult and needs perfection. We can have lots of false alarms, which could lead the team ignoring the alarms without investigation. The most simple way to get rid of this intrusion is to use static, read-only entries for the services in the ARP cache. There exists a good number of research efforts presenting intelligent methods to get rid of this intrusion.

Table IX shows some effective detection and prevention systems of ARP intrusion.

L. Ping of Death Attack

A ping of death (PoD) sends a malicious ping to a computer. The maximum size of an IPv6 packet including the IP header is 65,535 bytes. Many ancient computers [88] cannot handle this large size of packets and will crash if it receives one. This attack exploits early TCP/IP implementations including Windows, Mac, Linux and other network devices like router and fax etc. Since sending packets in large form causes IP fragmentation by attacker, targeted system can get lot of ICMP packets via ping without waiting for the reply. Once the system becomes vulnerable to this attack, other attacks may dig in like Trojan horse. Cloud flare protection can demolish the PoD attacks before they reach the targeted host. There is no specific works related to this attack. Certainly, some DDoS attack related paper added the solution of this intrusion as a small part of it. The low rate [89] “Ping of death” attack, dubbed BlackNurse, effects firewalls from Cisco, Zyxel, and possibly Palo Alto in 2016.

Fig. 12 shows a general model of such attack. In this figure, BOT have sent ICMP spoofed ping messages in the network. The server will broadcast ping flood resulting in other PCs connected with the server unable to work. This mostly happens on the data link layer. This attack is less common today as many computers are immune to this attack. Generally in this attack, attacker transmits malformed or oversized packets exploiting ping command that results in system crash.

One of the solutions is to add a verification to reassemble the function to make sure data packets size don’t get maximized. Other solution can be creating a memory buffer to handle the space of every incoming packets . Cloud flare

TABLE IX. STATE-OF-THE-ART SOLUTIONS OF ARP INTRUSION

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Ghazi et al. 2016 [83]	ARP table, ARP filtering, authenticating	✗	✓	All ways of ARP spoofing is not discussed and detected.	Defense implementation	Not mentioned	Yes	Yes
Sweta et al. 2018 [84]	Secondary ARP table	✓	✓	Time interval between hosts is fixed. Authorized connection may take longer time can be concluded as attack.	Real time implementaion	Not mentioned	Yes	Yes
Jing et al. 2019[32]	ARP reply message process in OpenFlow platform	✓	✗	The system is not flexible enough to integrate	Discussed new features in OpenFlow network	Min. Min.5679.76 Max.8307.89 Avg. 7919.66 S.D 404.60	Yes	Yes
Sanguankotchakorn et al. 2019[85]	Hybrid controller	✓	✗	Detecting Switched DDoS attack is taking around 9 seconds which is really slow.	Discussed Controller mitigation process	Entropy falls 1 to 0 with time	Yes	Yes
Sanguankotchakorn et al. 2019[86]	A non-cryptography-based and called MR-ARP	✓	✗	It takes longer time to determine the secure path	Analyzed Mitigation technique	Not mentioned	Yes	Yes
Al-An et al. 2020[87]	Match-Prevention	✗	✓	the bandwidth consumption of Match Prevention is 18% higher	Discussed security challenges	100% success rate	Yes	Yes

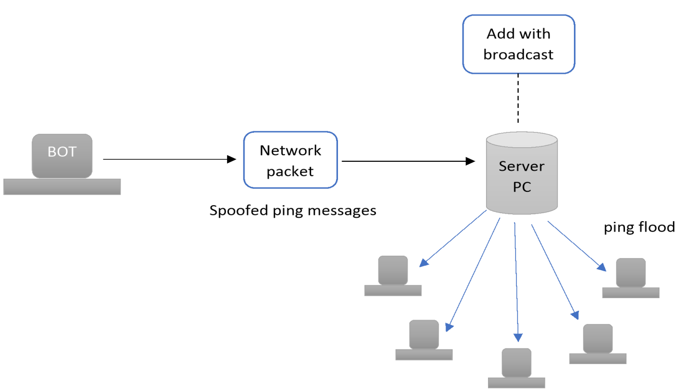

Fig. 12. Ping of Death: Spoofed Ping Messages Add with the Broadcast IP of the Server to Manipulate clients PC.

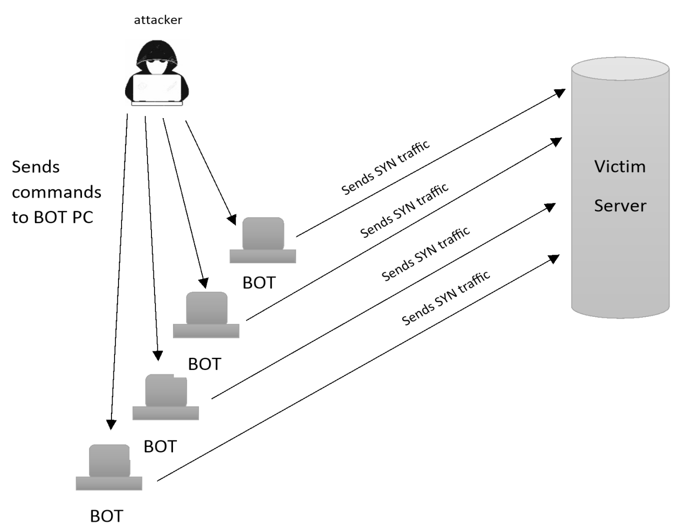

Fig. 13. SYN Flood Attack: Attacker Sends Command to BOT PC Sends SYN Traffic to Server.

protection can demolish the PoD attacks before making any harm to the PC [90].

There is no specific works related to this attack. Certainly, some DDoS attack related paper added the solution of this intrusion as a small part of it.

TABLE X. STATE-OF-THE-ART SOLUTIONS OF SYN FLOOD ATTACK

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Hussain et al 2016 [91]	Three Way Counter Algorithm for Attack Detection	✓	✗	Cloud security is not justified	HoneyPot method is emphasized	Attack detection rate of Tcp port 60%	No	No
Kshirsagar et al 2016 [92]	System architecture for efficient detection	✓	✗	Authors have used only 4 features to detect attack which is not efficient	load of CPU is minimized after The attack	Cpu load value ranges from 8-11% after detection	Yes	Yes
Kumar et al 2018 [93]	SAFETY	✓	✗	Victims from multiple destination can not be detected	SAFETY brings 13 percent regarding processing delay experienced by a legitimate node	100% TPR while has approximately 27% FPR	Yes	Yes
Bae et al 2018 [94]	DDoS Cyber-Shelter model	✓	✗	Authentication data can get access to the service even during the attacks are made. Data can be manipulated	a cost-effective way	lowest false positive rate of 0.0003% at maximum	Yes	Yes
Zhong et al 2018 [95]	Three modules, such as sniffer module, analysis module and active defense module	✓	✓	Most network administrators do not have set up such rules, it gives potential attackers the convenience of attacks	provide reference for tracking SYN flood attack	Network administrators are no longer required	Yes	Yes
Khalid et al 2019 [96]	SYN Flood Attack Detection Based on Bayes Estimator (SFADBE)	✓	✗	Bandwidth issue exists	low cost and robust	threshold is 8.0	Yes	Yes
Dang et al 2019 [97]	SSP (a coordination of the SDN Open-flow switch)	✓	✗	94 percent accuracy which is not good enough for integration in a system	SSP improves the successful connection rate and average connection retrieval time	SSP can reduce the number of HOCs by 68% in case of 100 pkt/s rate, and by 86% in case of 500 pkt/s.	Yes	Yes
Evmorfos et al 2020 [98]	Random Neural Network with Deep Learning	✓	✗	Neural Network's recurrent structure needs to improve	substantially better attack detection and significantly lower false alarm rate	Accuracy False 80.7%	No	No

M. SYN Flood Attack

In a SYN flood attack, the attacker does not respond with the expected ACK to the server. Also, the attacker might spoof the source IP address in the SYN packets which causes the server to transmit SYN-ACK to a fake IP address. Due to the creation of a half open connection [99] [91], the malicious client consumes server resources unnecessarily and prohibits the server in establishing connections to the other clients. One of the ways of mitigating this attack is the use of Cloud flare between the target server and the SYN flood.

A well-documented DDOS attack was introduced in 1996 by panix. In 2005 [100] [101], the website of this company got hijacked again in the period of holiday. It took off their sleeps to get everything back together.

Fig. 13 depicts a sample scenario of this attack. In this figure, by sending initial connection request through SYN packets, the hacker makes the ports of the Victim server overwhelmed.

Some state-of-the-art solutions of SYN floods attack are presented in Table X.

N. Malformed Attack

Malformed packet consists of malware or other malicious elements. In this attack, a BOT PC sends incorrectly formed packets to the victim to crash the system by receiving attacker instruction. The massive combination of DDOS and IoT attacks have been blown up in late 2016. This is the largest one till now. It has extremely terrifying capability of exploiting about 1.2 TB per seconds. Best way to filter this attack is to allow legitimate traffic and discard floods of packets [102] like ICMP or UDP.

Categorizing it as follows: (i) IP address malformed attack and, (ii) IP packet malformed attack.

1) IP address malformed attack contains the same source and destination IP address which confuses the target system resulting in system crash.
2) In this attack, system is forced to process and waste additional time due to randomizing the optional fields in IP packet along with setting all QoS bit to 1 [103]. This attack might lead to the system crash if combined with multiple attackers [104].

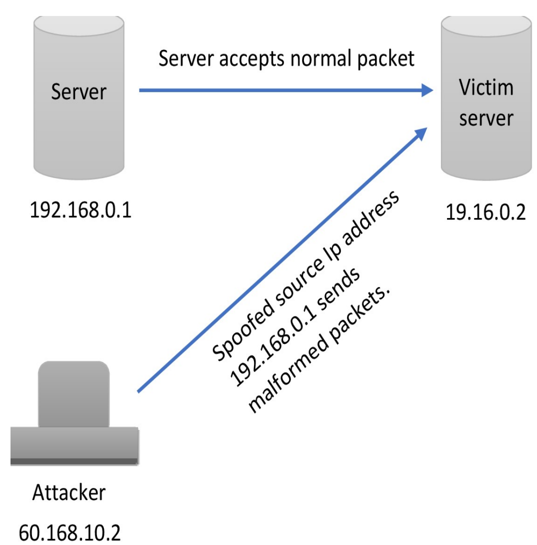

Fig. 14. Malformed Attack: Attacker Spoofed the IP Address to Send Malformed Packet to the Victim Server.

In the Fig. 14 attacker changes his IP address to source IP address 192.168.0.1 and acts as an legitimate server. By establishing connection with the server it sends malformed packet. Packet malforming leads to packet manipulation. A larger ping more than 65,535 bytes [105] is enough to conduct a attack. So attackers send it by fragments. If the victim tries to reassemble it, they will face oversized packet or memory over flow. It could crush PC or servers in the mean time

Some existing solutions related to this attack is enlisted in Table XI.

IV. Extrusion Events

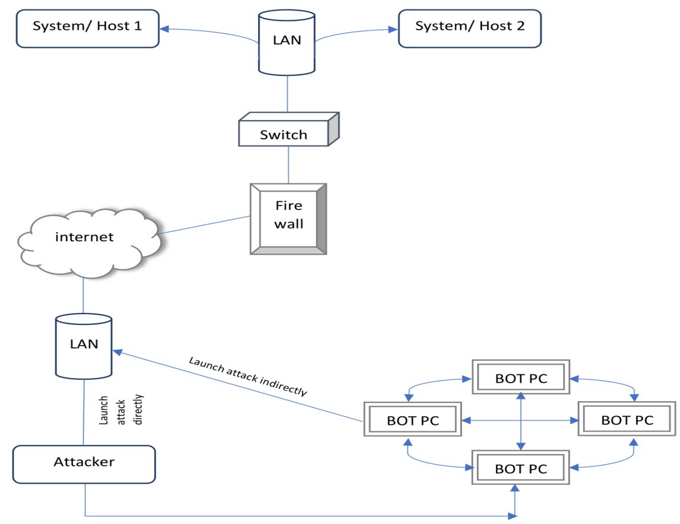

Fig. 15. A Generalized Model of Occurrence of an Extrusion Event.

In this section, we excavate the extrusion events. In what follows, we present their definitions, explain how they occur and outlined the possible solutions with necessary figures and tables, wherever applicable. As stated earlier, extrusion event might bring vulnerability to the remote system device by getting injected with malware or by opening a malicious web page etc.

Fig. 15 shows a generalized model of an extrusion in a system. Basically, in Fig. 15, two hosts are connected with the same LAN. LAN connects to the switch and switch connects to the internet. Firewall is the barrier between the attacker and the target. Also, numerous attackers and BOT PC (created by attackers) are connected with the internet through LAN. If any user of that host clicks on malicious websites, or opens malware related software, then extrusion may occur. As numerous attackers frequently upload malware through internet and also send phishing e-mails, it is highly probable to get infected by clicking malicious links or downloading malicious files. This section describes all possible extrusion events and the related existing counter measures.

A. Supply Chain Attack

According to November2018 study by Opus Ponemon Institute, 59 percent of organizations in UK and US has already experienced data tempering and compromised security issues by their third party stakeholders [107].

Fig. 16 shows a general model of a supply chain attack. In this figure, attacker changes the script of any targeted server which makes the server compromised. Eventually, the malicious or compromised server makes other server compromised and thus the chain continues.

Due to the repeated attack on different servers, it is almost impossible to detect it. Other attacks only target the victim

TABLE XI. State-of-the-Art Solutions of Malformed Attack

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Patil et al 2019 [105]	Threshold value set for detect malformed packet	✓	✗	The proposed mechanism misapprehends some malformed packets. However, they are dropped as excess flood packets due to crossing the threshold limit	All kinds of flood attack can be detected	Not mentioned	No	Yes
Venugopal et al 2019 [106]	Generates ACL	✓	✗	Legitimate IP addresses requires to be minimized to run the system	Detailed DDos attack	Not mentioned	Yes	Yes

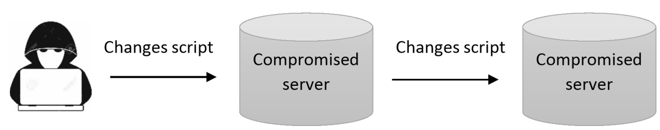

Fig. 16. A Chain System of Attack: an Attacker Changes the Script of the Server to Manipulate System

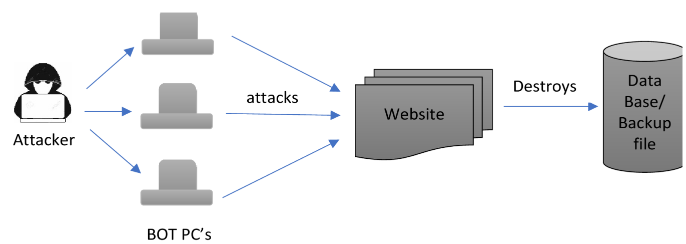

Fig. 17. DeOS Attack: Attacker Attacks the Main Structure of the Organization.

computer, but in this attack, the victim is not the ultimate target of the attack, rather stepping a stone to other networks. This attack mainly occurs on application layer. The 2013 attack against Target is the classic example of a supply chain attack. As the attack is new and very difficult to detect, no such paper has discussed about the solution to it.

B. Destruction of Services (DeOS) Attack

A destruction of services targets the entire organization's ability to recover from the attack afterwards. It is meant to damage the maximum amount possible, resulting in data loss, service disruptions and cost of data recovery. It puts business in such a position that either they have to rebuild their architecture from scratch or pay the money to the attacker.

In its 2017 Midyear Cybersecurity Report, Cisco said the rapid spread of WannaCry, for example, foreshadowed the emergence of what it is termed "destruction of service" (DeOS) attacks, which could present an existential threat and leave businesses completely unable to recover.

To defend against this attack, a system needs to check regular penetration test results, hiring more cyber security staffs and decreasing mean time to detect man in the middle destruction statistics. The quicker the threat is detected, less the damage occurs throughout the system.

In the Fig. 17 attacker commands the BOT PC's to attack the website of the organization to destroy the back up file or the database.

The two most common points of entry for attackers are through known exploitable vulnerabilities and acquired administrator credentials. This attack includes Cisco's 2017 that made Cisco worry to use creative ideas to mitigate the attack. The common default passwords, common default setting is also an concerned issue.

Popular destruction-of-service attack vectors include:

1) Business Email Compromise (BEC): Business email compromise attacks uses the ID of someone on the particular network to trick the victim into sending money or info to the attacker. The most common victims are those who use wire transfers to send money to international clients.

2) Cyberwarfare: Cyberwarefare generally refers to attacks that relate to cybernet. In every case, it has been observed that a terrorist group or hacker groups aimed at a particular nation or political organization to do their work done. This event is also new to the network system, and no specific solution has come out.

C. Distributed Denial of Services (DDoS) Attack

DDoS attack is a fraudulent attempt to make any service unavailable to the users. It can be launched from globally distributed compromised devices, also known as Botnet. It is hard to differentiate legal user traffic from malicious trafficn [108] when dispatched across many points of origin. This may cause long-term reputation damage.

The Google attack in 2017, the AWS DDoS attack in 2020, the Mirai Krebs and OVH DDoS attacks in 2016, the Mirai Dyn DDoS attack in 2016, the Six Banks DDoS attack in 2012 are the most famous DDoS attacks that caused most harm to the organization. Traceback approach has both prevention and

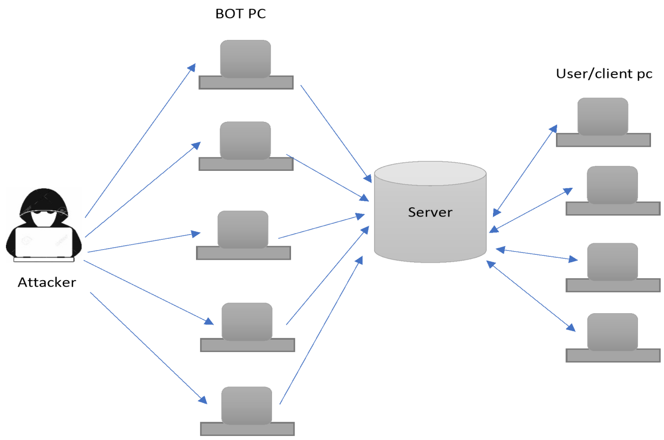

Fig. 18. DDoS Attack: Several Bot PCs Compromised the Server to Attack the Target.

detection method and also has an efficient code enhancement system.

Fig. 18 depicts a model of how DDoS occurs. In this figure, the attacker commands the BOT computer to send illegitimate traffic in order to flood the system server PC. From the system server PC, users/clients also get illegitimate traffic, causing the system unavailable.

It can be categorized into three types [109], which are:

1) Volume Based Attack: This attack is related with ICMP flood attack, UDP flood attack and also spoofed packet flood attack. Attacker intends to change the value of the bandwidth of victim's site. The parameter of this attack is measured in bits/second.

2) Protocol Attack: This type of attack is related with fragment packet attack, syn flood attack, ping of death and smurf attack and many more. Here, the attacker attacks attacks actual server data, communicating devices between hosts, firewalls as well as load balancer. The parameter of this attack is measured in packet/second.

3) Application Layer Attack: This attack is related with Post/Get php flood attack, slow attack and many more. Mainly the attacker targets the victim's windows or OpenBSD vulnerabilities. Attacker makes the victim believed that the request is innocent and legitimate. The main goal of the attack is to crash the main server of the system. The magnitude of this attack is measured in requests per second.

Solutions related to this event are presented in Table XII.

D. Phishing Attack

Phishing attack targets the victim's computer through mails, messages or via link by pretending to be a legitimate person or organization to lure the victim. By doing these, the attacker gets to know the victim's personal sensitive data [115] for example, ID card information, credit card information and passwords, etc.

In 2020, Doharty associate claimed their customer faced one phish, two phish, red phish, blue phish in the name of phishing attacks. They also fell for it and gave away their password details. Support vector machine and Naive Bayes algorithm have approximately 100% efficiency to defend any kind of phishing attacks.

Usually, the attacker performs the phishing attack using one of the following ways:

1) The attacker can hand over the important information.
2) Attacker spams out the phishing messages to many people, so that at least some people will be the customers of some specific bank or organization.

Phishing attack may be categorized as follows.

1) Spear Phishing: Spear phishing may attack a particular person of an organization often with content tailor made only for the victim. The attacker requires sufficient knowledge about the organization to produce such content. The content may relate to victim's colleagues, names and relationship with employees. With this kind of data, attacker may generate a trusted email.

2) Clone Phishing: The attacker attaches a malicious link or attachment utilizing a previously delivered valid email. Once the user clicks on the link, he becomes the victim. Then the attacker gets his desired information from that victim using certain measurements. Victim may give organization's confidential data to the attacker in some cases [116].

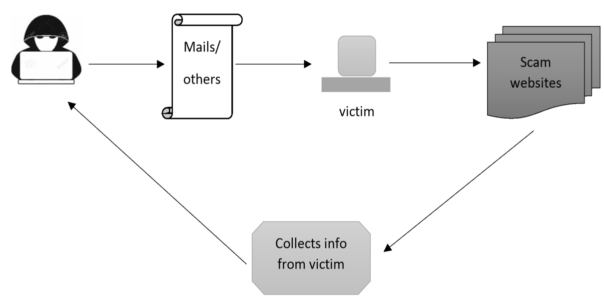

Fig. 19. Scamming a Victim's Computer using Phishing Attack: Attackers Send Mails to Victim's Computer to collect Information by Clicking on Scam Website .

Fig. 19 illustrates how a phishing attack takes place. In this figure, attacker sends malicious e-mails or other documents. If the user clicks on a link provided by an attacker given through a message, then he may provide his username, password, etc. to that website which may resemble as real but actually is a malicious site. Now attacker may enter into his account. Most of the messages are sent to the HR staff with the infected file that disguised as a job seeker's resume, for instance [117]. Most of these attachments are often zip files, or documents with embedded code. It plays a significant role in other attacks like Trojan and ransomware.

Some state-of-the-art solutions to this attack are presented in Table XIII.

E. URL Poisoning Attack

URL poisoning attack, also addressed as location poisoning, tracks down any web user's page sequence or information

TABLE XII. STATE-OF-THE-ART SOLUTIONS OF DDOS

Reference	Proposed Method/ Model	Detec-tion	Preven-tion	Limitations	Merit	Efficiency	Code modifi-cation	Applied to all platform
Alan et al 2016 [109]	Artificial Neural Network (ANN) algorithm	✗	✓	It is not designed for encrypted packets	detect DDoS attacks based on specific characteristic features (patterns)	98% accuracy	Yes	Yes
Zhuotao et al 2018 [110]	Umbrella	✓	✗	It hampers user's privacy	capable to deal with large scale attacks involving millions of attack flows	Accuracy 90%	No	No
Mehr et al 2019 [111]	SVM based solution		✓	Feature correlation needs be more precise. Traffic generation and real-time performance is missing	use time pattern for prevention	Ryu controller is reduced by 36% 7 yes	yes	
David et al 2019 [112]	Statistical approach	✓	✗	Real time implementation is missing.	higher detection rate and accuracy and lesser processing time	99.6% accuracy	Yes	Yes
Saxena et al 2020 [113]	A third party auditor (TPA)based packet traceback approach	✓	✓	Threshold value should vary with real time update.But the value is fixed.	Easy DDoS prevention in the cloud environment	97.4% accuracy	Yes	Yes
Wang et al 2020 [114]	Multilayer perceptrons	✓	✗	If feedback mechanism works incorrectly, the system will get wrong knowledge	correct the detector when it performed poorly	Accuracy 92%	Yes	No

by adding an ID when a user visits a particular website. Exploiting this ID thereafter, the attacker can determine the visited web pages. Accumulating this sort of information might be helpful to comprehend different user activities including how a user gets to a page, what he likes and so on. This may lead to tie in user behavior to demographics.

Israeli researcher Omer Gil has introduced a method called as deception attack. It has many advantages over cached pages. It mainly targets e-commerce and online payment gateway. This attack occurs on by exploiting cookies. In this attack, user may never find a way to opt out from the trap. A system that is infected by URL poisoning will assign an ID to the victim when he visits the first page. Then, this ID will be a part of the URL without victim's knowledge. All information related to this ID might be recorded as long as he visits the same page. It may also be attached with the browser when a victim visits any original site.

In Fig. 20, attacker intentionally enters ID to the victim's page and stores the number sequence. Further, attacker uses the data for the illegal purpose. Our rigorous exploration in this very topic reveals that no specific research works exist to the solution of this attack.

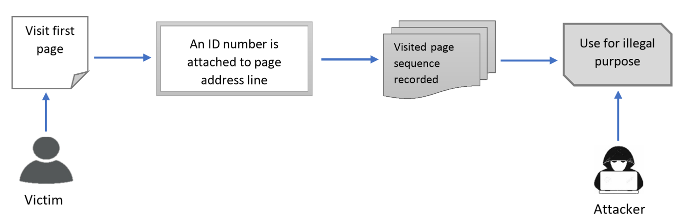

Fig. 20. URL Poisoning Attack: Victim's Visited Page is Recorded using ID Number.

F. Outbound Attack

A traffic that generates from the insiders is known as outbound traffic [127]. The main reason of locking down outbound attack as securely as inbound is DDoS attack. If an open port is not available to move out traffic, a system network may be immune to this event [128]. Fig. 21 shows a sample scenario of an outbound attack.

Outbound attack can lead to Wild botnet attack that maybe be worst case of this attack.

In this figure, hacker sends traffic to overwhelm the target

TABLE XIII. STATE-OF-THE-ART SOLUTIONS OF PHISHING

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Jain et al 2018 [118]	PHISH-SAFE: URL Features-Based Phishing Detection	✓	✗	Accuracy is relatively low.	trained using more than 33,000 legitimate URLs	90% accuracy	Yes	No
Adebowale et al 2019 [119]	An Adaptive Neuro-Fuzzy Inference System (ANFIS)based robust scheme	✓	✓	SVM still shows less accuracy than other algorithms	efficient and integrated features of images, frames and text of phishing websites	98.5% accuracy	Yes	No
Rao et al 2019 [120]	an application named as Jail-Phish	✓	✗	Similarity score may not be able to detect correctly every time	a real time application for the phishing detection	accuracy of 98.6%	Yes	Yes
Suleman et al 2019 [121]	Uniform Resource Locator (URL) based phishing detection	✓	✗	Prevention method is not discussed	Improved feature selection method	95 percent accuracy	Yes	No
Liew et al 2019 [122]	A supervised machine learning technique of Random Forest(RF)	✓	✗	Need real time implementation to show accuracy of the mechanism.	Analyzes 11 best classification features	accuracy 97.5 percent	Yes	no
Mao et al 2019 [123]	A learning-based aggregation analysis mechanism	✓	✗	F1 score is relatively low.	enable automated page-layout-based phishing detection techniques	93.7 percent accuracy	Yes	Yes
Jain et al 2019 [124]	A machine learning based approach	✓	✗	If any attacker alter page internal resources such as image, text, code etc then their approach will predict false result too.	language independent and detect the website written text	98.4 percent	Yes	No
Chiew et al 2019 [125]	A new hybrid ensemble feature selection framework	✓	✗	Computation-ally expensive.	automatic, flexible and robust feature selection	94.6 percent accuracy	yes	No
Orunsolu et al 2019 [126]	Support Vector Machine and Naïve Bayes algorithm	✓	X	If any attacker tries to copy a web page using advance tools, then the outlook of such website will be a replica of the legitimate page.	extracted features automatically	99.96% accuracy	Yes	Yes

PC. As, he sends payload with the traffic, target may click on this. Once clicked, the server is compromised. Nevertheless, the user also establishes outbound HTTPS connection with the attacker which surely tunnels back and takes control over the system. In most cases, the employee has no idea that they have been compromised, nor does their employer. In such a case, the computer needs to be reinstalled but at least the rest of the network will still be intact. If this connections [128] are restricted to specific protocols and can only be established by the specific users or authenticated users, then the attacks become ineffective.There is no specific research study found on this very topic.

G. Violating Traffic Regulation Conditions Attack

Traffic regulation [129] means to achieve the required quality of services goals such as bandwidth, load, delay,

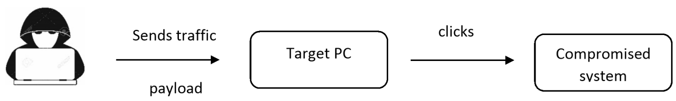

Fig. 21. Outbound Attack: Hacker Sends Payload to Target PC to Comprise the Server.

security etc. Our concern is the issue of security [130]. Policies that relate to traffic regulation might monitor the TCP connections on all IP addresses and ports in a system. IDS traffic regulation (TR) policies for TCP ports limits the total number of connections an application has been active at one time. Attacker may violate the traffic regulation policies by modifying TCP connection of the hosts . It could result in establishing TCP connection by the attacker with the target's host to do malicious activity. After successfully connected with the host, it takes full control over host. To the best of our knowledge, we have not found any significant research endeavors addressing the solutions on this attack.

H. Social Engineering Attack

Social engineering attack is one of the most popular and easy ways to get any information from any person that may relate to any organization. The attacker designs the process so deceivingly that any person may easily be manipulated. In the context of cyber security, this is used to lure victim to disclose sensitive data, perform security breaches or infect system unknowingly [136].

Shark Tank 2020, Toyota 2019, Cabarrus County 2018, Ethereum Classic 2017, Democratic Party 2016, Ubiquiti Networks, Sony Pictures, Target South Carolina Department of Revenue, RSA. etc. are the most popular social engineering attacks till date.

During the process of conversation, victims are not aware of the intention of the attacker. Therefore, they easily fall in trap. Many types of explicit methods are used to seduce or attract the victim to start a conversation [137]. It may be classified into two types which are, (i) Hunting and (ii) Farming [137].

1) Hunting approach executes the social engineering attack by doing minimum conversation between the target and the hacker. Once hacker is successful in getting the information, he terminates the conversation between them. This process is the most used one in the cyber world. It can encounter a single operand at once [138].
2) Social engineering farming is not something that is practiced often. This is used for some particular situations. To get the information, attacker needs longer period of time to keep himself connected with the user. During this process, the conversation or interaction may change between them. Some cases, target may understand the tactics. If not, then user may get blackmailed by the hacker [138].

In Fig. 22, attacker collects information about the victim and makes a customized attack for the victim. Then, he collects response from the victim and uses the sensitive information against him. The main focus of this attack is to ignore manual security process by deceiving user. They may get the weakest link to attack people emotionally [137].

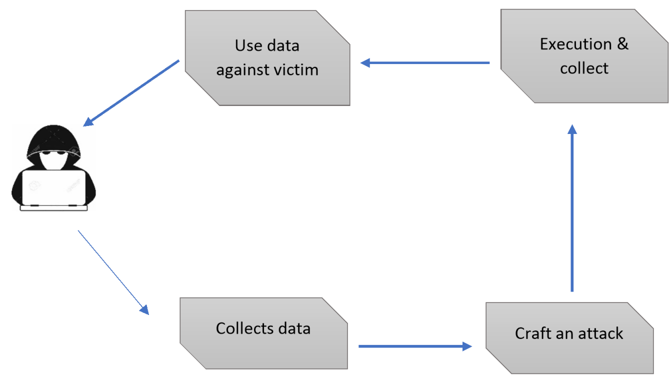

Fig. 22. Social Engineering Attack: Attack Phases.

Table XIV lists some existing solutions researched so far.

I. Malware Attack

Malware[139] can be a file or software program which is harmful for a system or computer. They may vary from function to function that can do theft, encryption or delete any important data, alter or hijack programs of a system, and monitor any activity of the users without their permissions. Attacker uses ways to spread the malware through physical or virtual means. Some malwares are automatically downloaded to the system as they are designed without the user's knowledge [140]. Some types of malware, that have new techniques, are designed to not only deceive the users but also to detour the anti-virus easily. Anti-sandbox technique can detect malware and delay execution after it leaves the sandbox [141].

Fear has been upgraded its level during the time of corona virus. Many cyber criminals, and ransomware are introduced in this period. Covidlock is one of them[142].

Some types of malware include the following:

1) Virus: A virus is a type of malware that may execute itself without any command and may spread on it's own.

2) Worm: A worm can replicate itself without any host or user program. It spreads itself without human intervention and is directed by malware attackers.

3) Trojan: A trojan virus disguised as legitimate to get access to a system. If it is activated, it starts to follow installations. It can execute their malicious actions by itself.

4) Spyware: Spyware is made to get a collection of information of data on a user device and monitor activity of the victim without their knowledge. It is like keeping an eye on users.

5) Ransomware: Ransomware infects a system, encrypts its data and demands a certain amount of ransom money from the victim in exchange for fixing the system.

6) Rootkit: A rootkit is created by a hacker to get access into the administration level of the target's system. If it is installed, the system gets threat from root or deep infrastructure.

TABLE XIV. State-of-the-Art Solutions of Social Engineering Attack

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Sawa et al 2016 [131]	Natural language processing techniques	✓	✗	Total CPU time for execution of all stages was 2421 seconds which is long	applicable to many attack vectors sincerely on dialog text	Precision 100 percent and recall 60 percent	Yes	No
Abeywardana et al 2016 [132]	A layered defence strategy SERA	✓	✗	Classification needs more enhancement.	Detailed information of attacks	Not mentioned	No	No
Dan et al 2019 [133]	Data Protection Mode	✓	✓	Attack ratio is still high enough to harm the organization.	Modular design, More state transitions and Incorporates and implements the data protection process	Not mentioned	Yes	Yes
Lansley et al 2019 [134]	A two-stage approach that detects social engineering attacks and based on natural language processing	✓	✗	More algorithm needed to evaluate the program for comparison.	evaluated using both real and semi-synthetic conversation points	accuracy 0.917	Yes	Yes
Mouton et al 2019 [135]	SEADM	✓	✗	The method is not adhered to every request.	Explored social engineering as a domain	Not mentioned	yes	Yes

7) Backdoor: A backdoor is a form of virus or remote access Trojan. It constructs a backdoor into a compromised system that facilitates the attacker for remote access without causing any disturbance of user's security issues.

8) Adware: The main purpose of the adware is to trail the browsing history of a user with the intention of displaying advertisements. This allures an user to make any purchase.

9) Keylogger: Keylogger is a type of monitoring system which nearly sees everything that users actually do on the computers including emails, web pages etc.

State-of-the-art research works on malware attack are depicted in Table XV.

J. IoT Botnet Attack

A group of computers, appliances and connected devices[149] [150] that have been controlled by a hacker or a hacker group for illegitimate purpose is known as IoT botnet. It is made up of computers that can be accessed remotely by a hacker without the victim's knowledge. It forwards the data to the other computers through internet. Botnets are increasing and have become more advanced since the evolution of IoT. It may target many devices and appliances on any infrastructure and inject them with malicious payloads or packets. The evolution of IoT increases the risk of security breaches [151][152].

In Fig. 23, The IoT is comprised of diverge devices including cameras, routers, DVRs, wearable and other embedded technologies.

Three botnets have been occurred in 2018. It gave rise to different domains, but all of them are inter connected. Each of them are skillful and ingenious system which can detect fraud. Google, White Ops, and other tech companies came together at that time to invade the operation of this attack.

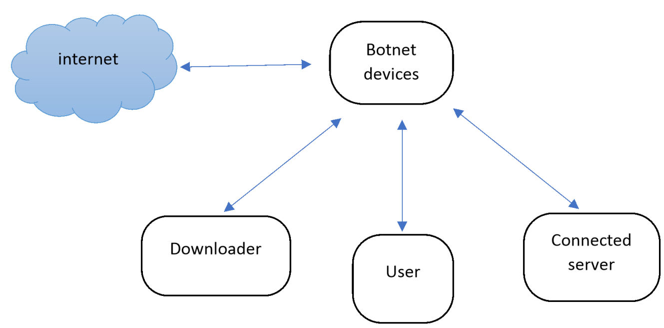

Fig. 23. Connected IoT Devices: Botnet Devices are Connected to Every Possible Device Through Internet.

As most of the devices are Linux and Unix based, they become the common target of the attacker. Since in those system, an executable format exists which is modifiable by the attacker. The modified file becomes the malware that targets SSH or telnet network protocols. Once the system is compromised, the payload is delivered to the system through installation and thus turned into a botnet. [153][154]. Some existing solutions related to this attack is summarized in Table XVI.

TABLE XV. STATE-OF-THE-ART SOLUTIONS OF MALWARE ATTACK

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Andrea et al 2018 [143]	MADAM	✓	✓	Performance measurement is missing	developed a binary rewriting tool	Not mentioned	Yes	Yes
Mishra et al 2019 [144]	VMANALYZER	✓	✗	Imbalanced dataset which leads to uncertainty in the normal traces of processes.	feature vector is build for each process in monitored TVM	4.7-100 percent accuracy	Yes	yes
Maiorca et al 2019 [145]	Command-and-control botnets	✓	✗	Details of methods are missing.	categorize known vulnerabilities of learning-based PDF malware	Not mentioned	Yes	No
Gan et al 2020 [146]	A dynamical propagation model	✗	✓	Adjusting system parameter is difficult.	discussed behavior of malware under an infected cloud environment	Not mentioned	Yes	Yes
Alazab et al 2020 [147]	An automated process by using a scoring and grouping technique	✓	✗	Use of more machine learning algorithms may achieve more accurate results.	assist in the process of malware forensic investigation	94.3 percent accuracy	Yes	No
Mishra et al 2020 [148]	KVMInspector	✓	✗	It is not incorporated with network monitoring functionalities	Considered as advanced security check	81.25%–99.92%(UNM) and 95.43%0–97.81%(Elog)	Yes	yes

V. INTRUSION AND EXTRUSION EVENTS: A BIG PICTURE

In this section, we have recapitulated all the intrusion and extrusion events by means of their types, how and where they occur, consequences and existing solutions, as presented in Table XVII.

TABLE XVI. State-of-the-Art Solutions of IoT Botnet Attack

Reference	Proposed Method/ Model	Detection	Prevention	Limitations	Merit	Efficiency	Code modification	Applied to all platform
Meidan et al 2018 [14]	N-BaIoT	✓	✗	Connection between IoT devices that has low prediction rate in their network is not allowed due to security polices.	Create experimantal setup for dataset	.0007 FPR	Yes	Yes
Tzagkarakis et al 2019 [155]	Sparsity representation framework	✓	✗	The decision threshold is estimated using only begin training instances.	Lightweight method	Not mentioned	Yes	No
Banerjee et al 2019 [156]	Honeynet	✓	✗	Malicious binaries, attack replays are not considered.	provides activity logs of the intrusion attempt	100 percent accuracy	yes	No
Dange et al 2020 [157]	CNN-based deep learning model	✓	✗	There is a difference in power consumption as it negotiates the condition of various WiFi signal.	details of IoT attacks	Not mentioned	Yes	No

TABLE XVII. SUMMARY OF INTRUSION AND EXTRUSION EVENTS

Attack name	Type	How it occurs	Where it occurs	Consequences	Existing methods/ models	Complexity
TCP ACK storm attack	intrusion	It can exploits a design architecture in the TCP specifications	Application layer	Effect the websites regular work by sending lots of traffic	Modifying the TCP ,State transition model, hypervisor at close state, FMVEA and multiset semantic, MLPNN structure	Low
Fraggle attack	Intrusion	Dispatches numerous numbers of malicious traffic to overwhelm a router's transmittable address in the network	Transport layer	Cripple any servers for hours, or even days	SACL filtering method	Low
An ICMP redirect message attack	Intrusion	A message is designed for informing a host that there is a more optimal route is available so that user may redirect to the malicious traffic system.	Transport layer	Cause problems in fire-walled environments where flow traffic patterns are non-deterministic	BigFlow Open Flow, PrECast proxy service, AR-match technique, Signature based and Machine learning tool, Centralized system	Low
Internet protocol fragment attack	Intrusion	Attacker uses the fragmentation protocol within IP to attack the system.	Transport layer	System may freeze or overwhelmed because of the attack	BGP Flowspec rules, Edwards-curve Digital Signature Algorithm, Sparsely-Tagged Fragmentation Marking approach, SecuPAN proposed tool, Integrated IP Source Address Validation Architecture (ISAVA)	High
Perpetual echo attack	Intrusion	Any illegitimate activity happens at port 7 in the form of spoofing any system knows as perpetual attack.	Transport layer	Large amount of network traffic causes delay.	Prey Predator (PP), Ant Colony Optimization, Modified protocol specifications	Low
Internet Control Message Protocol (ICMP) tunneling attack	Intrusion	Attacker inserts malicious data by using ICMP tunneling and echo the packet to remote computer	Network layer	Any sensitive data or access in private sector may done by this attack.	A novel mechanism of 5 algorithms, Covert Channel Detection using Support Vector Machine, Stateless and monitoring model, Stateless model	High
Smurf attack	Intrusion	The attacker creates a malicious network packets attached to a IP and send it to the victim's system	Network layer	It can freeze company servers for days and months. Data loss can happen	SDN based technique, an enhanced History-based IP Filtering scheme, Pattern Matching Techniques, principal component analysis	High
Router attack	Intrusion	Injecting vulnerabilities to the router	Network layer	Attacks impact network services and business operations distributed router shadow, an Interest flow balancing method, Run-time protector and Restart-time protector.	Distributed router shadow, an Interest flow balancing method, Run-time protector and Restart-time protector, Pushback method, Scalable Method	Low
Slow and fast port scan attack	Intrusion	May blend into the network noise never exceeding detection thresholds and exhausting detection system state	Network layer	Creates changes in the normalcy of the traffic	Distributed router shadow, an Interest flow balancing method, Run-time protector and Restart-time protector, Pushback method, Scalable Method, Exposure map, Distributed Cooperative Model, ADRISYA, Scan Chain Encryption, Classification algorithm, time-aware metrics in NIDS evaluations, Fuzzy Rule Interpolation	High

Attack name	type	How it occurs	Where it occurs	Consequences	Existing methods/ models	complexity
Restricted IP attack	Intrusion	Attacker restricted the access to the particular site and defined set of IP address	Network layer	Restrict user's website	ARP table update state-based detection approach, SQL Injection detection mechanism , An adaptive framework, Packet filtration, payload distribution model, generic authorization framework	Low
ARP attack	Intrusion	When a hacker dispatches false ARP messages to the local network and connect it with the system.	Data link layer	Hackers can steal sensitive information from the targeted computers.	Discrete event system, IP probing, ARP table, ARP filtering, Centralized methodology (central server), Novel mechanism, Secondary ARP table etc.	Low
Ping of death attack	Intrusion	Attacker sends malicious ping to a system to flood the system.	Data link layer	It can crash, damage or freeze the victim's computer by sending oversized malformed packet	No specific solution	low
SYN floods attack	Intrusion	Connected with syn false packet and TCP connection established	Data link layer	Attacker makes the system unavailable for the user by flooding with legitimate traffic.	GT-IDS-DJ Method, Three Way Counter Algorithm for Attack Detection, system architecture for efficient detection, The Adaptive threshold algorithm and the cumulative sum (CUSUM), DDoS Cyber-Shelter model, three modules, such as sniffer module, analysis module and active defense module, AR modeling, SYN Flood Attack Detection Based on Bayes Estimator (SFADBE), SSP—a coordination of the SDN Open-flow switch	Low
Malformed attack	Intrusion	Incorrectly formed IP packets are formed and sent to the victim to crash the system	Data link layer	The system of the victim may get confuse and gets crashed	TCP trace module, Threshold value set for detect malformed packet, Generates ACL	Low
Supply chain attack	Extrusion	A value-chain or third-party attack occurred by an outsider	Application layer	Causes major data breach	No solution yet	High
DeOS (destruction of services) attack	Extrusion	Targets an organization's entire online presence as well as their ability to recover from the attack afterwards	Application layer	Could put businesses in a position where they have to rebuild infrastructure from scratch or pay a high ransom to the attackers	No solution yet	High
Distributed denial of services (DDOS) Attack	Extrusion	Malicious attempt to make an online service unavailable to users	Application layer	Make any website or system and servers unavailable to legitimate users	Graphic model, central control of SDN, Artificial Neural Network (ANN) algorithm , Umbrella, SVM based solution, statistical approach, a third party auditor (TPA)based packet traceback approach , An Unsupervised Approach, multilayer perceptrons	Low

Attack name	type	How it occurs	Where it occurs	Consequences	Existing methods/ models	complexity
Phishing attack	Extrusion	Targets are contacted via email,text or link disguised as legitimate institution	Application layer	Steals Sensitive information	An Adaptive Neuro-Fuzzy Inference System (ANFIS), Jail-Phish, URL-based detection system, light-weight deep learning algorithm, Uniform Resource Locator (URL) based method, supervised technique of Random Forest(RF), learning-based aggregation analysis mechanism, Machine Learning techniques and algorithms etc.	High
URL poisoning attack	Extrusion	Track the identification number added by the attacker in the web browser and gets information from that victim when he/she visits the particular site	Transport layer	Tracks user to get desired information	No specific solution yet	High
Outbound attack	Extrusion	Attacker tunnels back in over that connection to take control of the employees' computer	Network layer	Unlimited email or file transfers might let the attacker enter into the network and get sensitive information outside	No specific solution yet	Low
Violating Traffic regulation conditions attack	Extrusion	Violating traffic regulations	Network layer	Causes any discontinuity to the network normal behavior	No solutions yet	Low
Social engineering attack	Extrusion	Gather information about someone by exploiting human weakness that inherits every organization	Network layer	Can control one life through virtual manipulating	Data Protection Mode, two-stage approach that detects social engineering attacks and based on natural language processing, SEADM, CANDY, SMS-based second factor authentication, multi-layered shield, natural language processing techniques, layered defence strategy SERA	High
Malware	Extrusion	Any program or file that is harmful injected through any way in the system	Data link layer	It thefts, encrypts, or deletes the data. It can spy on computer activity without user knowledge or permission	A dynamical propagation model, an automated method by using a scoring and grouping technique, KVMInspector, VMANALYZER, command-and-control botnets etc	High
IoT botnet	Extrusion	It is accessed from a remote computer without the owners' knowledge and set forward transmissions to other computers on the Internet	Physical layer	It causes breaches to all related IoT devices	N-BaIoT, IoT-BAI model, CNN-based deep learning, MOPSO, sparsity representation framework, Honeynet	High

End of Table

VI. Open Challenges and Future Research Issues

Theoretically, it is expected from computer security mechanisms to prevent attacks and to provide solutions to the threats. If not impossible, it should be capable of predicting future threats. As a consequence, towards fulfilling this expectation, researchers around the globe are working to design, develop and implement increasingly secure systems.

Our effort of excavating numerous research papers conveys what aspects of intrusion and extrusion have been studied and what have not. What concerns us the most is that there is no unified policy or mechanism exists that could be applied to an enterprise system to tackle the possible intrusion or extrusion events. We strongly believe that there is a need for a smart system that might learn and take effective countermeasures against the impending threats. Therefore, we would like to make suggestions for future directions to the research community.

One of the challenges is to build new data sets. Due to the rapid advancement of technology, innovative attack methods also evolve. Protocol developed using existing old data sets do not reflect the impending innovative threats to be mitigated or neutralize. As a natural consequence, research on this very issue requires tremendous attention.

With the advent of deep learning technique, security research got new research dimension. However, one of the limitations of using this in security, particularly in intrusion detection, is to balance between high accuracy and minimal false alarms. This limitation mainly presents in the Convolution neural networks (CNN). Also, using Feed-forward neural networks (FNN) for multi-class classification is a limiting factor. The third limitation includes performance degradation in IDS under heavy traffic load. Furthermore, using Deep Neural Network (DNN) causes higher execution time due to the larger training dataset. However, developing new methods using deep learning, if not impossible, might mitigate the mentioned limitations.

One of the important concerns regarding present research endeavors is that researchers apply variations of machine learning, if results are convincing, they conclude their methods may be applicable for certain scenarios. However, we argue that an interpretable or explainable reasons should be there is to why certain machine learning methods work better.

Software defined network (SDN) mingled with machine learning approaches is the new trends in IDS. However, SDN itself might be the interest to the attacker. This obviates to excavate the vulnerabilities in SDN. On a different note, since SDN network controller suffers from performance degradation for larger network, new research efforts are essential to address the challenge.

We believe that each attack is unique and attackers are very intelligent. Irrespective of the nature and severity of attacks, the future research on this domain should consider not only the detection and prevention of existing attacks but also should predict the future threats. If not impossible, if that is achieved to a certain extent, research community may render meaningful and fruitful contributions to the society.

The difficulties that lay ahead of us in infiltration and extrusion detection systems have grown significantly in recent years. The following is a list of them.

- Inability to decrease the amount of false positives, reducing IDS efficiency. A good IDS should have a high level of accuracy and recall, as well as a low rate of false positives and false negatives. A key concern is how one can have faith in the outcome.
- The amount of time it takes to analyze such a vast amount of data for training is enormous.
- In IDS, improving classification accuracy is a significant goal. It forces to concentrate on a multi-classifier system.
- Due to a lack of computer resources and a significant increase in targeted assaults, a real-time intrusion detection system is urgently required. However, putting it into practice in a real-world setting is difficult.
- A problem is the lack of a common assessment dataset that can mimic real-time IDS.
- Many research employ the selection of functions to reduce the computer complexity in function reduction work. To carry out the data deduction task, greater focus is necessary.
- A combination detection and anomaly detection approach is necessary.

It's not an amazing mountain to create an effective detecting system. The above mentioned difficulties might greatly contribute to this trip.

VII. Conclusion

Network attacks are a daily security concern that may be mitigated. As a result, it is critical to explore more complicated security alternatives than simple firewall systems today. This article discusses numerous forms of attacks on TCP/IP networks at each layer, the merits and limits of Intrusion Detection System (IDS) and Extrusion Detection System (EDS) solutions, IDS and EDS efficiency and code environment, and utilized techniques for both.Some intrusion detection systems have progressed significantly, and the data generated by software and the tactics used by attackers are getting increasingly sophisticated. This makes it difficult to discern between genuine system use and potential infiltration. A false alarm, also known as a false positive, occurs when an IDS erroneously detects an activity as a probable intrusion.Poorly designed intrusion detection systems, particularly behavior-based intrusion detection systems, can generate a large number of false positives. In the case of passive-response intrusion detection systems, this might result in an overwhelming administrative load (getting paged for a false alarm every 3 minutes becomes annoying very quickly). In the case of active-response IDS, this might potentially result in a DoS situation.If the IDS incorrectly blocks a valid user's IP address. As a result, before adopting an IDS, considerable preparation and thought are required. The paper isolates the concerns and concentrates on why IDS and EDS are required for delivering secure network service. Because one of the most important criteria for enabling privacy is security.Loss or unauthorized access, deletion, use, alteration, or disclosure of personal data should all be safeguarded by appropriate security precautions. Work on system design and algorithm design for secure communication over complicated networks can be done in the future.

In this paper, we have provided the thorough survey and the state-of-the-art of existing intrusion and extrusion events and introduced a refined security analyses by means of threats, counter measures and future research directions. The comprehensive review presented in our work may provide designers with new means to look for solutions in a unified manner according to several security and resource parameters. Finally, we are aware that attacks other than those considered in this paper might exist. We strongly believe that addressing provable security of intrusion and extrusion events is a challenge for future research, but not impossible.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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Identifying Central Nodes in Directed and Weighted Networks

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***Abstract*—An issue of critical interest in complex network analysis is the identification of key players or important nodes. Centrality measures quantify the notion of importance and hence provide a mechanism to rank nodes within a network. Several centrality measures have been proposed for un-weighted, un-directed networks but applying or modifying them for networks in which edges are weighted and directed is challenging. Existing centrality measures for weighted, directed networks are by and large domain-specific. Depending upon the application, these measures prefer either the incoming or the outgoing links of a node to measure its importance. In this paper, we introduce a new centrality measure, *Affinity Centrality*, that leverages both weighted in-degrees as well as out-degrees of a node's local neighborhood. A tuning parameter permits the user to give preference to a node's neighbors in either incoming or outgoing direction. To evaluate the effectiveness of the proposed measure, we use three types of real-world networks - migration, trade, and animal social networks. Experimental results on these weighted, directed networks demonstrate that our centrality measure can rank nodes in consonance to the ground truth much better than the other established measures.**

Keywords*—Centrality; weighted network; directed network; migration network; world input output trade network; community structure

I. Introduction

Data analysts from diverse domains represent relationships or ties between entities using graph-based network models. The semantic meaning of nodes and ties is, however, domain-specific; in social networks where nodes represent individuals, ties might represent friendship or face-to-face communication [17], [2] whereas, in web networks, ties signify the existence of hyperlinks between web pages [16]. In most real-world networks, ties are characterized by their strength as well as direction. For instance, in world trade networks, where links between nations represent the exchange of commodities, tie strength is the cash flow and its direction indicates either import or export [6]. When both the strength and direction of ties are available, modeling data as *weighted, directed network* can be more elucidative and revelatory.

Network models are generally deployed to explain or predict the behavior of entities [11]. One key requirement in these applications is to determine the 'most important' or 'central' node in a network. A centrality measure quantifies this notion of node importance and provides a means to rank nodes based on their importance. Central nodes are useful in varied applications such as predicting most cited authors [22], determining influential spreaders for product advertisement in online social networks [12], [25], detecting influential criminals [9], performing resilience analysis of power grid networks [13], locating key areas of activity in the urban infrastructure of a city [1], and traffic sampling for intrusion detection [28].

Several centrality measures have been formulated to quantify the notion of central nodes in un-weighted/ weighted, un-directed networks and are surveyed in [7], [3], [4], [5]. However, quantification of node centrality is more challenging in complex weighted and directed networks due to the dynamic effect of weighted reciprocal links on its computation. Very few measures exist for such networks, and the area remains under-explored.

A. The Problem and Motivation

PageRank (PR) proposed by Brin and Page to rank web pages is a popular and effective centrality measure [20], and there exist variations and extensions of PR for weighted, directed networks [27], [30]. These measures quantify the importance of a web page by iterative counting of the number and quality of its incoming links. The underlying assumption is that more important web pages have more *incoming* links from other central web pages. The problem is that this assumption, though correct for web pages, may not be valid for other domains. For example, in the migration networks, a state's importance in the network is affected not only by the incoming migrant population but also by the outgoing migrants from that state.

A pair of centrality measures that consider both incoming and outgoing links are computed through the Hyperlink-Induced Topic Search (HITS) algorithm for web pages. However, this method delivers two metrics - hub score and authority score [14]. A good hub page has *outgoing* links to many good authorities; a good authority page has *incoming* links from many good hub pages. Similarly, the recently proposed Bi-directional h-index also presents two measures, h_{in}-index and h_{out}-index that give preference to incoming and outgoing links, respectively [29].

This raises a critical question regarding the importance of *incoming* versus *outgoing* links when computing the relative importance of a node. We conjecture that, in some domains, incoming links have more impact than outgoing links, whereas, in others, it is vice versa. This trade-off offers the opportunity to define a novel measure that can tune the relative importance between incoming and outgoing ties.

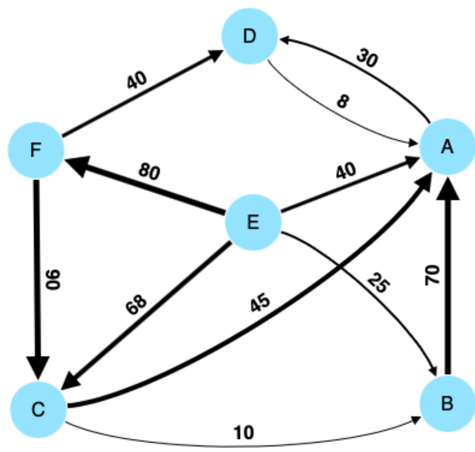


Fig. 1. Example Network.

Consider the example network shown in Fig. 1 modeled as a citation network where nodes are authors and weighted incoming link from author A to author B indicates the number of times A has cited B. In citation networks, importance of an author is commensurate with the number of citations, therefore incoming links should be given preference for computing centrality. Highly cited authors are more important, and if the citations are from other highly cited authors, then the importance should increase proportionately. In the example network, author A is the most central by virtue of receiving the highest incoming links (citations). Authors C and D receive citations from two authors each. Although author C gets more citations compared to D, the centrality of D should be high because of being cited by highly cited authors compared to C.

On the other hand, if the network in Fig. 1 is an organizational network of employees and weighted outgoing link represents the number of tasks assigned by employee A to employee B, then outgoing links should be preferred for computing the importance. An employee at higher position supervises a large number of employees and has the privilege to assign more tasks to them. Such an employee has higher importance in the organization compared to others. Following this hypothesis, employee E is the most central because this node has maximum outgoing links. Between employees F and C with equal number of outgoing links, employee F should be considered more important than C because F receives tasks from other important employees.

In the same vein, for applications such as analysis of trade or migration networks, both incoming and outgoing links could be given user specified weightage.

Recognizing these requirements, we propose a new centrality measure called *Affinity Centrality* that determines the importance of a node based on preference and influence proportions of its local network. We propose an intuitive upgradation of simple yet powerful weighted degree centrality by incorporating neighbors' attachment with the node. The quantum of centrality contributed by a node's neighbor is decided by the relative proportion of its incoming/outgoing interactions. A tuning parameter permits the user to flexibly assign more weightage to either the in-neighbors or the out-neighbors of a node. Our centrality measure leverages only local node topology, which distinguishes it from well-established PageRank and HITS methods. Despite its simplicity, the measure is able to rank nodes in a better consonance to the ground truth than these established measures.

B. Our Contributions

We introduce Affinity Centrality ($\mathcal{AC}$), a centrality measure for weighted and directed networks. The summary of contributions follows.

- We propose a tunable centrality measure for quantifying the importance of a node by combining the advantages offered by its neighbors' topology via incoming and outgoing links (Section III).
- We perform an extensive evaluation of $\mathcal{AC}$ on real-world migration and trade networks and compare its effectiveness with well established centrality measures (Section IV-B).
- We demonstrate empirically the effect of the tuning parameter in capturing the relative importance of the incoming versus outgoing ties (Section IV-C).
- We evaluate the role of central nodes delivered by the proposed centrality measure on the community structure of real-world networks (Section IV-D).

C. Organization of the Paper

The paper is organized as follows: after a survey of centrality measures for weighted and directed networks in Section II, we present the proposed centrality measure ($\mathcal{AC}$) in Section III. Section IV presents empirical investigations followed by conclusions in Section V.

II. Related Work

Vast literature exists for centrality measures designed for un-weighted and un-directed networks [5], [19], [12], [10], [18]. However, computing centrality for weighted and directed networks still faces some gaps in terms of incorporation of the direction of interactions in the computation. We briefly describe the existing work for directed and weighted networks by dividing them into two categories viz. i) Local-neighborhood based and ii) Global network structure based measures.

In the local-neighborhood based class, a node's importance is computed based on its interaction with l-hop neighbors where l indicates the number of hops. Opsahl et al. proposed a generalized centrality method to incorporate impact of degree along with the strength of interactions using a tuning parameter which can be tuned to give importance to either of the two aspects [19]. However, the proposed mechanism considers either incoming or outgoing direction in computation. Neighborhood centrality computes importance based on the centrality of a node and its 2-hop neighbors' centrality for un-directed and weighted networks [18]. The absence of direction in computation reduces its applicability to directed networks.

Global network structure based methods consider the influence of all nodes on the importance of a pivot node. Two established algorithms in this category are HITS [14] and PageRank [20], that measure the probability of a random walker visiting a node on the web to assign a rank. HITS gives two scores Hub and Authority based on the direction considered whereas PageRank does ranking using incoming interactions only. Various extensions to these two algorithms have been proposed to extend them to directed weighted networks [29], [30], [24]. Zhang et al. proposed a weighted Pagerank algorithm for directed networks that incorporated the role of a node's degree, its strength and the node information using a tuning parameter to compute its rank [30]. Wang et al. modified the efficiency centrality for un-directed and weighted networks and incorporated both the degree and distance of all the nodes in a network [26]. Singh et al. proposed hybrid node-weighted centrality measures based on closeness and decay measures and made use of node information along-with edge weight to identify important nodes [23]. However, the high computational complexities of global network based algorithms make them unsuitable for large networks.

Designing an effective ranking measurement to capture the importance of nodes in a directed and weighted network is still an open challenge. Our proposed measure *Affinity Centrality* fills this gap by encapsulating both types of interactions along with their strength in the computation of the topological significance of a node in the network.

III. Affinity Centrality for Weighted and Directed Network

This section describes the proposed centrality measure called *Affinity Centrality* that leverages auxiliary information in a node's 1-hop neighborhood to determine its importance.

A. Notations used

Let $G(V, E)$ be a weighted and directed network of order $N = |V|$, size $M = |E|$ where V denotes the vertex set and E denotes the edge set. The network G can be represented by an asymmetric weighted adjacency matrix $W := (w_{ij})$ of size NXN where $N = |V|$. Each element $w_{ij} \in \mathbb{Z}^+$ represents the strength of the interaction from node i to j and $w_{ij} = 0$ represents no interaction. We use $w_{i\to j}$ and $w_{i\leftarrow j}$ to refer to the strength of outgoing and incoming ties of node i, respectively.

Let O_i denotes the total strength of all the outgoing ties and I_i denotes the total strength of all the incoming ties of a node i i.e $I_i = \sum_j w_{i\leftarrow j}$ and $O_i = \sum_j w_{i\to j}$. Hence, total edge weight $T = \sum_i I_i = \sum_i O_i$. In case when weights are unknown, $W = A$ where $A := (a_{ij})$ is the standard adjacency matrix having $a_{ij} = 1$ if nodes i and j are adjacent, otherwise 0. Notations used in the paper are detailed in the Table I for ready reference.

B. Constituents of Node Importance

A directed and weighted network, in general, consists of asymmetric interactions, and the direction of an interaction along with its weight emulates the preferential attachment of individuals in their neighborhood [8], [27], [19], [30]. The importance of a node depends upon its bonding with its local neighbors, which depends upon the strength and direction of the interactions. We refer to weight on an incoming edge as *in-strength* and weight on an outgoing edge as *out-strength*.

TABLE I. Interpretation of Notations Used

Notation	Interpretation
G	Network
V	Vertex set
E	Edge set
N	Order of G
M	Size of G
W	Weighted adjacency matrix
T	Total incoming/outgoing strength
O_i	Total outgoing strength of node i
I_i	Total incoming strength of node i
L_i	1-hop neighbors of node i
$w_{i\to j}$	Strength of outgoing tie from node i to node j
$w_{i\leftarrow j}$	Strength of incoming tie of node i from node j

We define the following two components based on the link interactions of a node with its direct neighbors.

i. *Preference*: Favors from in-neighbors indicate their endorsement for an individual. For a node i, $\frac{w_{i\leftarrow j}}{O_j}$ determines the endorsement from its neighbor j. The higher the value, the more preferentially attached the node i is with node j. Also, the influence gained through preferential attachment increases if the endorsement for the node j within its local neighborhood is high too. In other words, resources gained by an individual show its power which is captured by its total in-strength (I_j). Formally, preference (β_i) of a node i with neighborhood set L_i is defined in the Eq. 1.

$$\beta_i = \frac{1}{T} \sum_{j \in L_i} \frac{w_{i\leftarrow j}}{O_j} I_j \tag{1}$$

ii. *Influence*: The strength of the outgoing ties of a node i demonstrates its influence on its neighbors and captures its endorsement (preferences) for others. A higher value of $\frac{w_{i\to j}}{I_j}$ indicates a high influence of node i on node j. Also, the influence of a node i propagates in the network through its neighbors, which is captured through their out-strength O_j. Collective endorsement of the neighbors along with an individual's support impacts its influence on others. Formally, influence γ_i of a node i is computed as given in the Eq. 2.

$$\gamma_i = \frac{1}{T} \sum_{j \in L_i} \frac{w_{i\to j}}{I_j} O_j \tag{2}$$

C. Affinity Centrality

The importance of a node depends upon its structural position in the network which depends upon its interactions with neighbors. We compute the proposed *affinity* centrality ($\mathcal{AC}$) by incorporating effect of *preference* and *influence* of neighbors on the node i, using a tuning parameter $\theta \in [0, 1]$ (Eq. 3). Note that θ gives flexibility to the end-user to include either of the in-strength and out-strength or both based on the application need.

$$\mathcal{AC}_i = \theta\beta_i + (1-\theta)\gamma_i \tag{3}$$

Using $\theta = 1$ will reveal the influence of in-degree neighborhood on a node's *affinity*, in contrast to $\theta = 0$, that captures influence using its endorsement for neighbors. Using $\theta = 0.5$ will incorporate the role of both *influence* and *preference* on the node's position in the network structure. The higher the position is, the more powerful/important that node is. For example, in trading, the importance of a supplier is dependent on imports as well as exports. Importing from the established suppliers increases its endorsement, whereas exporting to powerful vendors improves its position in the trade. Hence, $\theta = 0.5$ is recommended in such scenarios. In case, influence is to be captured purely on the basis of imports/exports, then $\theta = 0/1$ is recommended.

To substantiate the argument, we rank nodes of the example network (Fig. 1) by computing $\mathcal{AC}$ with varying values of θ. The ranks are shown in Table II. With $\theta = 0$, only outgoing links are considered for capturing centrality; hence node E is assigned the highest rank, and node F is ranked above C. With $\theta = 1$, outgoing links are ignored resulting in node A being ranked highest, and node D ranked above C. The results validate the motivation (see subsection I-A) and establish the theoretical formulation of the proposed centrality measure.

TABLE II. RANKING BY $\mathcal{AC}$ MEASURE USING $\theta = \{0, 0.5, 1\}$ OF NODES IN EXAMPLE NETWORK (FIG. 1)

Node	$\theta = 0$	$\theta = 0.5$	$\theta = 1$
A	5	1	1
B	4	6	5
C	3	3	3
D	6	4	2
E	1	2	6
F	2	5	4

D. Algorithmic Complexity

As the method exploits information of the nodes' neighborhood to quantify centrality, the computational complexity is $O(M)$. The proposed method is effective for handling large networks due to its $O(M + N)$ storage space requirements.

IV. EXPERIMENTAL EVALUATION

The goal of this section is to assess the performance of the proposed Affinity Centrality ($\mathcal{AC}$) on the basis of the following questions.

i. How effective is the ranking delivered by $\mathcal{AC}$ measure?
We inspect this question in Section IV-B using six weighted and directed real networks for which ground-truth can be crafted.

ii. How does in-strength and out-strength impact the ranking computed by $\mathcal{AC}$ measure?
This investigation is done to demonstrate the role of *preference* and *influence* components on the importance of a node using a small sized weighted and directed network.

iii. What is the role of topological central nodes on the community structure?
We examined this question by extracting communities of the six networks and studied their evaluation in terms of important nodes delivered by the proposed centrality measure.

We evaluated the performance of $\mathcal{AC}$ measure by comparing its results with two simple and widely used local centralities viz. Weighted in-degree (WI) and Weighted out-degree (WO). We also compare the results with the two global structure based algorithms viz. PageRank [20] and HITS [14] for weighted, directed networks.

We implemented our proposed measure $\mathcal{AC}$ and variation of degree centrality - Weighted in-degree (WI) and Weighted out-degree (WO) in Python (64bits, v 3.6.9) and executed on Intel Core i3-4005U CPU @1.70GHz with 4GB RAM. We used the modules PageRank and HITS of the graph library networkx[1] of Python for comparison. Results of the experimentation are discussed in the following sub-sections after the description of networks used.

A. Real-world Networks

We consider three types of directed and weighted networks - migration, trade and animal networks to investigate the effectiveness and stability of the proposed $\mathcal{AC}$ measure. Description of these publicly available networks are detailed below.

i. We use Indian migration data of Census 2001 and Census 2011[2] for two factors viz. business and education to study the role of movement of population on state dynamics. For year $X \in \{2001, 2011\}$, we extracted the number of migrants for all possible pairs of 27 Indian states for each factor separately and created datasets named as *EducationX* and *BusinessX*. A dataset is mapped to a network by representing a state as a node and connecting a pair of states by a directed edge where direction captures the movement of migrants from the source state to the destination state. The absence of an edge between any two states indicates no migration between them. The number of migrants between two states is used as edge weight.

ii. The World Input Output Network (WION) represents the transaction volumes (in million United States Dollars) between 56 sectors of 43 countries in the world[3]. A few of the sectors to name are - Water Transport, Construction, Telecommunications, Real estate activities, Publishing activities, Education, Fishing and Aquaculture. The transaction volumes of these sectors from a country (say A) to country (say B) are added to get the total transaction volume and vice versa. The countries are represented using the country codes which are used worldwide, for instance - CHN represents China, ESP represents Spain, and so on. Note that the data of the country named as ROW(rest of world) is not considered as it indicates transaction volumes to and from the rest of the world and is not associated with a particular pair of countries. We use WION data for two years - 2004 and 2014 which are named WION2004 and WION2014. Each dataset is mapped to a network by taking a country as a node. Two nodes are connected by a directed edge if and only if there is an import/export transaction between them and the volume of the transaction is used as the edge weight.

[1] https://networkx.org/
[2] https://censusindia.gov.in/
[3] http://www.wiod.org/database/wiots16

TABLE III. Properties of Six Weighted and Directed Networks, CC: Average Clustering Coefficient, WD: Weighted Density

Category	Network	CC	Diameter	Transitivity	Reciprocity	WD	Size	Order
Migration	Business2001	0.92	2	0.91	0.94	738	617	27
	Education2001	0.95	2	0.95	0.95	565	662	27
	Business2011	0.91	2	0.90	0.92	758	609	27
	Education2011	0.94	2	0.94	0.94	621	646	27
Trade	WION2004	0.98	2	0.95	0.96	2078	1715	43
	WION2014	0.98	2	0.98	0.99	4013	1768	43
Animal	Moreno-Rhesus	0.61	4	0.59	0.76	2.7	111	16

iii. The Moreno Rhesus monkey grooming network represents a network of 16 monkeys[4]. The network consists of 16 nodes representing the monkeys and a weighted edge from a monkey (say A) to another monkey (say B) represents the number of times the monkey A groomed monkey B. We use this small network to demonstrate the role of the introduced tuning parameter (θ) on the node centrality.

Topological and structural properties of these networks are given in the Table III.

B. *Effectiveness of the Affinity Centrality*

We study the effectiveness of the proposed centrality measure $\mathcal{AC}$ by using six real networks in two categories: migration and trade. The topological characteristics of the networks are detailed in Table III. To evaluate the performance of the centrality measures, we consider the Gross Domestic Product (GDP) of a state/country as ground truth because it is the most commonly used measure of economic activity and stability during a period of time (typically 1 year). Higher GDP of a state/country indicates richness in terms of resources and services and raises the living standards of its residents by offering more jobs, business opportunities, etc..

We compare the performance of the $\mathcal{AC}$ measure with four popular centrality measures viz, i) In-strength (WI) ii) Out-strength (WO) iii) Weighted Pagerank (PR) and Weighted HITS (both hub and authority scores). For each centrality measure, we rank nodes such that rank 1 is assigned to the largest value and so on. Spearman's rank correlation coefficient [21] is used to find the correlation of computed node ranks with ground-truth ranks, where correlation value indicates the ability of centrality measures to deliver correct ranks.

Table IV shows the ranking assigned by different measures to the top-10 ranked nodes as per GDP (first column in the table) for six networks. Ranking by $\mathcal{AC}$ measure is computed using $\theta = 0.5$ to include an equal, fair proportion of the two components viz. *preference* and *influence* on a node's importance. The last row of the table shows the correlation value. For all networks excluding Business2001, $\mathcal{AC}$ identifies the top-ranked nodes most accurately. Also, rankings assigned by $\mathcal{AC}$ are in better agreement with the ground truth compared to other measures, as indicated by the largest correlation (shown in bold). This is attributed to the inclusion of the relative importance of two components in capturing importance. Hence, $\mathcal{AC}$ stands out as the most effective performer for capturing importance in weighted directed networks.

[4]http://konect.cc/networks

C. *Effect of Tuning Parameter*

This section demonstrates empirically the effect of the tuning parameter (θ) in capturing the relative importance of incoming versus outgoing ties using the animal network shown in Fig. 2 where edge size reflects the proportional edge weight. We use $\theta \in \{0, 0.5, 1\}$ to show the role of both components *preference* and *influence* on the node ranks (shown in the Table V). We examine the ego-networks of three nodes M1, M4, M5 (Fig. 3) to study the role of θ on a node's importance. In the figures, I indicates total in-strength and O indicates total out-strength of the neighbor.

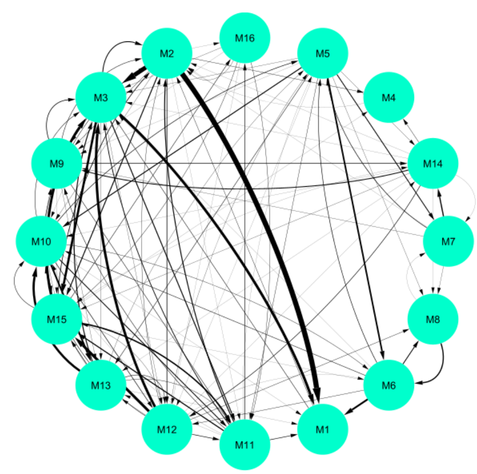


Fig. 2. Moreno-Rhesus Animal Network.

i. Table V shows that node M1 is assigned extreme ranks for $\theta = 0$ and $\theta = 1$, where value 0 or 1 indicates inclusion of a node's *preference* or *influence* component in centrality computation. Consider Fig. 3a for analysis of ranks for different θ values. When $\theta = 0$ is used, measure $\mathcal{AC}$ assigns a low rank to M1 because of its low influence on its outgoing neighbors M2 and M3 which themselves are less preferred nodes in their neighborhood (low value of I). On the other hand, $\theta = 1$ results in a high rank because of the high preferences of its three neighbors (M2, M3, M6) for node $M1$ where preferences are in proportion to in-strength of neighbors (Fig. 3a). High proportions of in-strength of three neighbors (M2, M3, M6) indicate their high preferences for the node which improves the rank of M1. Also assigning equal weightage to both components of importance ($\theta = 0.5$) results in a middle rank as both the preference from the neighbors and the influence to neighbors together impact its importance.

TABLE IV. Top-10 States/Countries Ranked by Their GDP and their Ranks by Six Centrality Measures

(A) Business2001

State	$\mathcal{AC}$	WI	WO	PR	Hub	Authority
Maharashtra	2	2	4	2	3	2
Uttar Pradesh	3	11	1	10	2	16
West Bengal	4	3	7	4	7	3
Andhra Pradesh	9	7	12	5	15	7
Tamil Nadu	12	13	6	9	9	11
Gujarat	1	1	5	1	5	1
Karnataka	8	4	13	3	14	5
Rajasthan	5	17	2	16	1	17
Madhya Pradesh	14	10	11	11	6	9
Punjab	10	16	8	14	12	13
Correlation	**0.90**	0.73	**0.90**	0.78	0.85	0.72

(B) Business2011

State	$\mathcal{AC}$	WI	WO	PR	Hub	Authority
Maharashtra	1	1	4	1	5	2
Uttar Pradesh	3	7	2	7	2	13
Andhra Pradesh	9	6	12	4	11	6
Tamil Nadu	12	13	7	11	9	10
Gujarat	2	2	5	2	4	1
West Bengal	6	3	6	5	6	3
Karnataka	8	4	13	3	8	4
Rajasthan	4	17	1	14	1	16
Madhya Pradesh	11	11	11	8	7	7
Kerala	17	19	14	17	12	20
Correlation	**0.91**	0.79	0.89	0.82	**0.91**	0.79

(C) Education2001

State	$\mathcal{AC}$	WI	WO	PR	Hub	Authority
Maharashtra	1	1	16	1	20	2
Uttar Pradesh	2	4	1	6	1	7
West Bengal	8	6	7	11	8	5
Andhra Pradesh	12	13	4	9	7	14
Tamil Nadu	9	9	9	7	13	13
Gujarat	11	11	5	5	3	12
Karnataka	4	3	13	2	6	3
Rajasthan	14	12	6	13	5	10
Madhya Pradesh	7	5	12	4	10	4
Punjab	15	16	10	12	14	17
Correlation	**0.81**	0.70	0.78	0.77	0.73	0.65

(D) Education2011

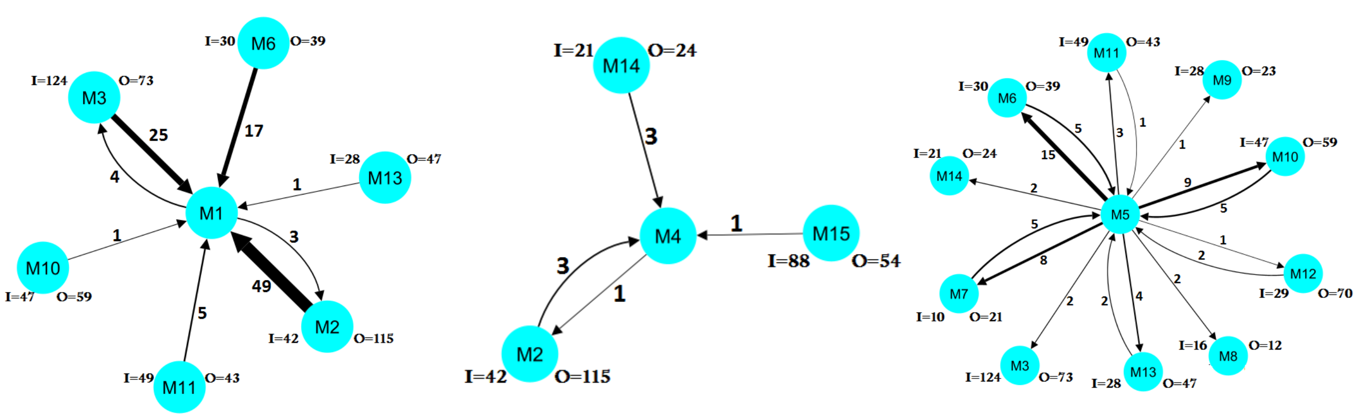
State	$\mathcal{AC}$	WI	WO	PR	Hub	Authority
Maharashtra	1	1	13	1	16	2
Uttar Pradesh	2	4	1	6	1	5
Andhra Pradesh	10	11	5	7	10	15
Tamil Nadu	8	8	12	4	13	14
Gujarat	13	10	8	5	3	11
West Bengal	11	9	9	14	11	8
Karnataka	4	3	15	2	8	3
Rajasthan	7	7	4	11	5	7
Madhya Pradesh	9	6	7	9	6	4
Kerala	14	22	3	18	4	22
Correlation	**0.85**	0.75	0.78	0.79	0.75	0.71

(E) WION2004

Country	$\mathcal{AC}$	WI	WO	PR	Hub	Authority
USA	1	1	1	1	3	1
JPN	6	7	5	8	5	7
DEU	2	2	2	2	2	2
GBR	3	4	3	4	6	4
FRA	4	3	4	3	7	3
CHN	5	5	8	5	8	6
ITA	8	6	7	6	9	9
ESP	10	9	13	9	15	10
CAN	7	8	6	7	1	5
KOR	12	13	12	13	11	12
Correlation	**0.94**	0.91	0.93	0.91	0.92	0.91

(F) WION2014

Country	$\mathcal{AC}$	WI	WO	PR	Hub	Authority
USA	1	1	1	1	3	1
CHN	3	3	3	3	2	2
JPN	6	6	7	9	6	7
DEU	2	2	2	2	4	3
GBR	5	5	6	5	8	8
FRA	4	4	5	4	10	5
BRA	19	18	19	21	16	15
ITA	10	8	10	6	12	11
RUS	13	19	11	16	14	20
IND	23	20	23	23	18	17
Correlation	**0.91**	0.90	**0.91**	0.87	0.90	0.90



(a) Local Neighborhood of Node M1

(b) Local Neighborhood of Node M4

(c) Local Neighborhood of Node M5

Fig. 3. Directed Weighted Local Networks of Nodes M1, M4 and M5 of Moreno-Rhesus Animal Network, I: Total in-Strength of the Node, O: Total Out-Strength of the Node.

TABLE V. RANKINGS BY $\mathcal{AC}$ MEASURE USING $\theta = \{0, 0.5, 1\}$ FOR MORENO-RHESUS ANIMAL NETWORK

Monkey	$\theta = 0$	$\theta = 0.5$	$\theta = 1$
M1	15	6	2
M2	1	2	4
M3	3	1	1
M4	16	16	16
M5	5	9	12
M6	9	10	8
M7	12	13	15
M8	13	14	13
M9	11	11	7
M10	2	4	6
M11	8	5	5
M12	4	7	9
M13	7	8	10
M14	10	12	11
M15	6	3	3
M16	14	15	14

ii. In contrast to node M1, the ranking of node M4 remains the same (although low) for all cases as shown in Table V. It is always ranked lowest because of its minimal influence on its out-going neighbor (M2) and low proportion of preferences from its incoming neighbors M2, M14, M15 having high values of I and O (Fig. 3b).

iii. Node M5 has a large in-degree and out-degree compared to node M1, but with low interaction strength. When $\theta = 0$ is used, the high influence of node M5 on its influential neighbors with high out-strength rises its rank (Fig. 3c). For $\theta = 1$, the node is ranked 12^{th}, which is comparatively lower than the rank assigned to node M1. A lower rank is attributed to lower preferences from its neighbors although the value of in-degree is high (low value of in-strength and I). When $\theta = 0.5$, node M5 is ranked in the middle due to the cumulative effect of both components on its structural position in its egonet.

D. Central Nodes and Community Structure

The objective of this section is to detail the role of central nodes delivered by the proposed measure $\mathcal{AC}$ on the evolution of communities. Communities provide a good insight into the connection patterns and binding among nodes. We use community detection module *Rbpots* [15] of library *CDLIB*[5] in Python to extract communities from the directed and weighted networks. Extracted communities are plotted using *Paintmaps*[6] where a color scheme is used to differentiate communities based on the interaction strength of underlying nodes. We executed the *Rbpots* module to identify communities in four networks of migration class and two networks of trade class. The plots are shown in Fig. 4. We compared the extracted communities for two different years under the same class to understand their evolution in terms of change in node ranking. We describe below our observations using the top-10 nodes delivered by the measure $\mathcal{AC}$ (Table VI) for two categories of networks.

i. **Business-based migration network:** Fig. 4a and 4b show the communities for networks Business2001 and Business2011. All states retained their community membership in 2001 and 2011, except Uttar Pradesh. Three top-ranked states Gujarat, Maharashtra, and Uttar Pradesh in 2001 resulted in a bigger community (red color) whereas Delhi (rank=7) created a community with its neighborhood in the northern Indian region (Table IV (A)). A significant increase in the *preference* term of Uttar Pradesh caused an upgrade in its rank such that it appears in the top-10 states in place of Punjab whose *preference* increased slightly and *influence* decreased quite significantly from 2001 to 2011. This led to the removal of Uttar Pradesh from the red colored community in 2001. This splitting may be attributed to a significant increase in incoming migrants in Uttar Pradesh in 2011 compared to Punjab in the same year.

ii. **Education-based migration network:** Fig. 4c and 4d show the communities for networks Education2001 and Education2011 where the number of communities remains the same. In 2011, the *preference* of West Bengal decreased significantly while its *influence* increased slightly due to which the pink colored community in 2001 split into two parts. In 2011, the *preference* of Andhra Pradesh increased significantly, and thereby it is placed in the top-10 ranks. This resulted in the merging of the eastern states of the split community with the community formed around Andhra Pradesh.

iii. **Trade network:** We identified communities for two trade networks WION2004 and WION2014 to understand the role of central nodes in the community formation (Fig. 5a and 5b). Three communities are formed with the only change in membership of Brazil. The rightmost two columns of Table VI show the top-10 ranked countries for both the networks. China (CHN) is ranked higher by the measure for WION2014 network, which is attributed to a significant increase in both its *preference* and *influence* terms from 2004 to 2014. Also, an increase in the trade interactions of Korea with other countries leads to a notable increase in both its *preference* and *influence* and thus it is placed in top-10 ranks delivered by the proposed measure in 2014(see column WION2014 of Table VI). In the same year, Brazil's interactions with Asian countries like China, India, Japan etc. increased compared to North American countries. The reduced trade with Northern American countries compared to Asian countries not only enhanced its rank, but pulled it out from its earlier community and placed it with communities in Asia (see Fig. 5b).

E. Discussion

The proposed centrality measure $\mathcal{AC}$ captures important nodes effectively compared to other centrality measures in Migration and Trade networks. This is attributed to incorporation of both in-strength and out-strength of the node with its 1-hop neighbors by setting tuning parameter $\theta = 0.5$. On the other hand, the compared centrality measures either consider in-strength or out-strength in computation which results in loss of information and thereby deteriorates the results.

[5]https://cdlib.readthedocs.io/en/latest/
[6]https://paintmaps.com

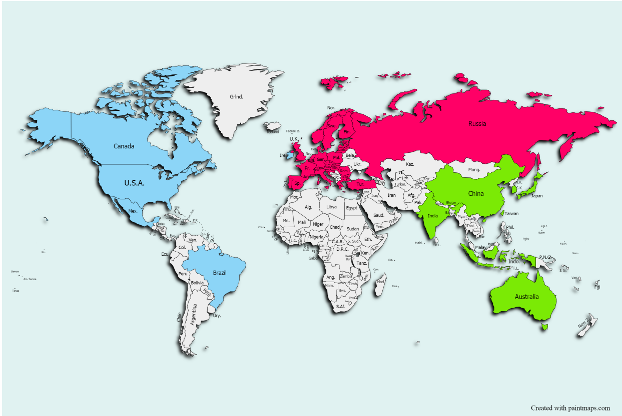
(a) Business 2001

(b) Business 2011

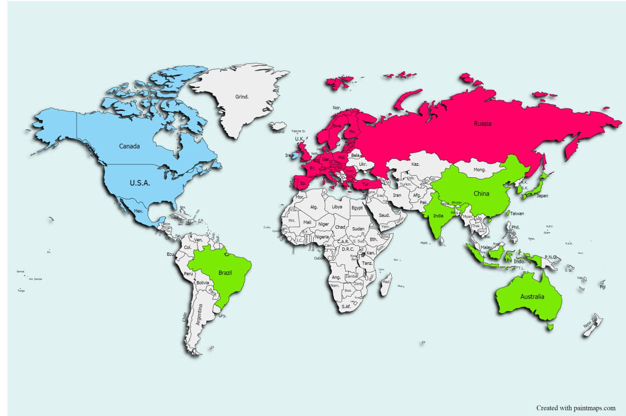
(c) Education 2001

(d) Education 2011

Fig. 4. Communities Extracted for Four Indian Migration Networks.



(a) WION 2004



(b) WION 2014

Fig. 5. Communities Extracted for Two Trade Networks: WION2004 and WION2014.

TABLE VI. Top-10 Ranked Nodes by $\mathcal{AC}$ Measure using $\theta = 0.5$ for Migration and Trade Networks

Migration Networks				Trade Networks	
Business2001	**Business2011**	**Education2001**	**Education2011**	**WION2004**	**WION2014**
Gujarat	Maharashtra	Maharashtra	Maharashtra	USA	USA
Maharashtra	Gujarat	Uttar Pradesh	Uttar Pradesh	DEU	DEU
Uttar Pradesh	Uttar Pradesh	Delhi	Delhi	GBR	CHN
West Bengal	Rajasthan	Karnataka	Karnataka	FRA	FRA
Rajasthan	Bihar	Bihar	Bihar	CHN	GBR
Bihar	West Bengal	Jharkhand	Jharkhand	JPN	JPN
Delhi	Delhi	Madhya Pradesh	Rajasthan	CAN	CAN
Karnataka	Karnataka	West Bengal	Tamil Nadu	ITA	NLD
Andhra Pradesh	Andhra Pradesh	Tamil Nadu	Madhya Pradesh	NLD	KOR
Punjab	Haryana	Kerala	Andhra Pradesh	ESP	ITA

Results on Animal network demonstrate that quantum of associations (*Preference* and *Influence*) of a node with its neighbors impacts its centrality in the network. Hence, the inclusion of incoming and outgoing interactions in the computation is application-specific and the centrality measure needs to incorporate them as per the application need. The tuning parameter θ of the proposed metric provides this facility. Also, central nodes as determined by $\mathcal{AC}$ play a vital role in binding their neighbors together in communities.

V. Conclusion and Future Work

In this paper, we propose a centrality measure, called *Affinity Centrality* ($\mathcal{AC}$), to determine key nodes in weighted, directed networks. The importance of a node is computed by leveraging its *preference* for and *influence* on its local neighborhood. These components of $\mathcal{AC}$ are computed by summing proportionate in-strength and out-strength of 1-hop neighbors, respectively. A tuning parameter $\theta \in \{0, 1\}$ gives flexibility to the end-user to include either the incoming or the outgoing or both types of neighbors depending on the application domain. To verify the effectiveness of $\mathcal{AC}$, we used three types of weighted and directed real-world networks - migration, trade, and animal social networks.

An empirical study based on these diverse networks demonstrates the effectiveness and superior performance of $\mathcal{AC}$ compared to the prevailing centrality measures. As for future work, we expect to further generalize the proposed metric by incorporation of l-hop neighborhood. However, the present work can be substantially improved to provide a generalized centrality metric that not only consider strength and direction but also incorporate topological characteristics of the network as well as auxiliary node information to deliver a more robust ranking.

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Real Time Vehicle Detection, Tracking, and Inter-vehicle Distance Estimation based on Stereovision and Deep Learning using YOLOv3

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***Abstract*—In this paper, we propose a robust real-time vehicle tracking and inter-vehicle distance estimation algorithm based on stereovision. Traffic images are captured by a stereoscopic system installed on the road, and then we detect moving vehicles with the YOLO V3 Deep Neural Network algorithm. Thus, the real-time video goes through an algorithm for stereoscopy-based measurement in order to estimate distance between detected vehicles. However, detecting the real-time objects have always been a challenging task because of occlusion, scale, illumination etc. Thus, many convolutional neural network models based on object detection were developed in recent years. But they cannot be used for real-time object analysis because of slow speed of recognition. The model which is performing excellent currently is the unified object detection model which is You Only Look Once (YOLO). But in our experiment, we have found that despite of having a very good detection precision, YOLO still has some limitations. YOLO processes every image separately even in a continuous video or frames. Because of this much important identification can be lost. So, after the vehicle detection and tracking, inter-vehicle distance estimation is done.**

Keywords*—Stereovision; stereo image; YOLOv3 deep neural network; convolutional neural network; vehicle detection; tracking; bounding boxes; distance estimation

I. Introduction

Today, there are millions of vehicles authorized on the roads and their number is constantly increasing. Consequently, traffic efficiency, reducing congestion and the human and material damage related to accidents, has become a major challenge in cities. However, this has been progressively improved in the last decade using ITS Intelligent Transport Systems (ITS). As a result, the incorporation of new information and communication technologies into vehicle interiors and transportation infrastructure has significantly revolutionized the way we travel today. These tools improve traffic flow by reducing travel time and congestion, detect road violations, support drivers, and reduce the risk of road accidents, and minimize the damage resulting from unavoidable accidents. These applications also impose demands, requiring credible dedicated hardware and reliable and timely communications. In addition, most traffic management systems are based on camera-based video surveillance because of their low cost, ease of maintenance, and ability to capture high quality images of the traffic scene [1]–[4]. This allows the dissemination and collection of useful information between vehicles, and transport infrastructure and vehicles to help drivers travel safely and comfortably.

However, these systems are reliable under normal conditions. In fact, they may not work very well in special circumstances, such as occlusion, bad weather, changes in lighting, and so on [1]–[3], [5]–[9].

In the present study, we are mainly interested in the calculation of inter-vehicle distance, which is an important traffic factor to be studied in intelligent transportation systems [2], [5], [8][1,5,6]. The aim of this paper is to present the possibility of using stereo cameras instead of LIDAR to estimate the inter-vehicle distance [1], [5]. Indeed, this method is advantageous because the recordings made by the cameras can be adapted for many algorithms. In addition, cameras are a much cheaper and therefore more cost effective solution compared to LIDAR [3]. Therefore, the images were captured by a stereoscopic system using two cameras placed above the traffic lanes. Indeed, our system consists of two slightly displaced cameras that obtain two images and go through a measurement algorithm based on the principles of stereoscopy in order to estimate the distance to the detected vehicles. The proposed solution is notably based on YOLO Deep Learning which will allow us to detect and delimit vehicles in a stereo image [7], [8].

The rest of the document is organized as follows. First, Section 2 gives a description of our stereo vision system. Then, we talk about calibration and stereo synchronization. In Section 3, we present our method of inter-vehicle distance estimation based mainly on the YOLO V3 Deep Neural Network algorithm and then we remove the general structure of our computational algorithm. In Section 5, a literature review on CNN models and YOLO model is given. The brief explanation of background of fully connected neural network is also provided. In Section 6 explanation of the experiment flow and methodology is given and overall system design is explained. Then, the test validation results, and the experimental results are explained. Finally, a conclusion is drawn.

II. Stereoscopic Vision System

A stereovision system is characterized by the acquisition of two images of the object to be observed from two different angles. After acquiring two images of an object from two different angles, the image coordinates of the points to be measured are determined on each of them. The matching of similar points is usually done automatically. The result is a list of 3D coordinates In fact, each of the two acquired images is processed by classical image processing tools to produce a list of 2D points characteristic of the objects. Each image having produced a list of points, a matching is then necessary to determine which points of the left and right lists correspond to each other. This matching can be based on a priori of the observed scene such as the preservation of the order of the elements from one image to the other. This constraint most often imposes to have two similar images or, in other words, to position the cameras very close to each other. Once the $(x, y)_l eft$ and $(x, y)_r ight$ pairs have been created, the calibration models can be used to calculate the corresponding (x,y,z) world points.

Therefore, the goal of stereovision is to calculate the spatial position of points from the coordinates of their images in two different views, in order to make measurements or to reconstruct the three-dimensional structure of the scene. So, the problematic of stereovision revolves around two essential points: camera calibration and synchronization. Indeed, at the shooting level, it is obviously necessary to obtain images of the same scene [3]–[5].

To acquire stereo images, we have designed a stereoscopic system with two similar cameras fixed and aligned on a stereo bar. The whole system was installed on a bridge over the highway, as shown in the following Fig. 1 [4], [5].

Fig. 1. Stereo System Installed on a Bridge over the Highway [1,8]. Stereo System Hardware Platform.

The calibration of a single camera (monocular applications) is equivalent to estimating its intrinsic parameters and its position in relation to the world reference frame. Configuring a stereoscopic sensor means calibrating both cameras (intrinsic parameters of each camera) and the relative position and orientation of the two cameras. Thus, calibrating a camera means estimating the transfer function that transforms a 3D point of the scene into a 2D point of the image.

Therefore, calibration is a very important step before the acquisition of the stereoscopic image [6], [10].

It allows to determine the intrinsic and extrinsic parameters of each camera. A bad camera calibration can influence the quality of the distance estimation. Therefore, the cameras must be installed accurately, otherwise measurement errors may occur (Fig. 2).

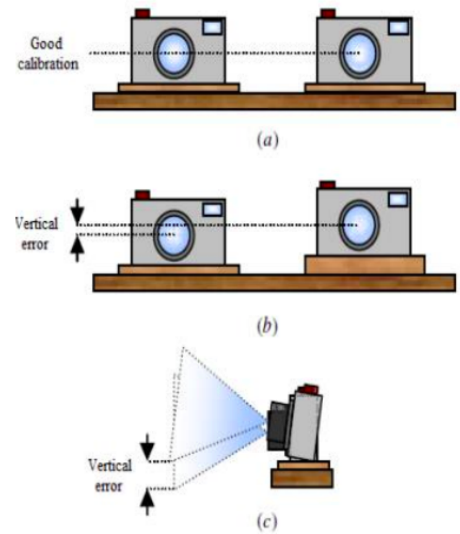

Fig. 2. Well-Calibrated Cameras (a), (b, c): the Most Common Calibration Errors.

The accuracy of the system depends on its correct calibration. Generally, we have two types of calibration [3]–[5]:

- Internal calibration to adjust the internal parameters of the camera (focal length, lens aperture, etc.) in order to eliminate image distortion. The intrinsic parameters of the camera are the projection of the optical center in the image frame, the focal length, and the image distortion parameters.
- External calibration to adjust the position and orientation of the two cameras in order to make their optical axes parallel. The extrinsic parameters are the translation and rotation between the camera frame and the world frame. They allow to position each camera in the same reference frame; to avoid any kind of non-calibration of both right and left image (Fig. 3).

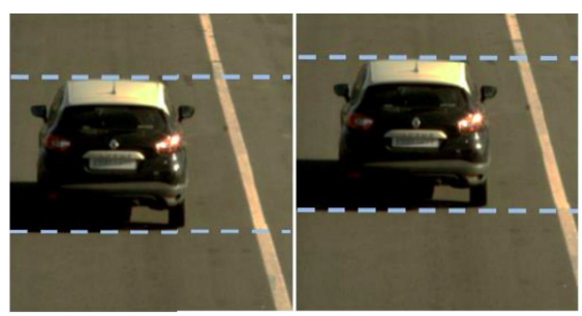

Fig. 3. Non Synchronized Pair of Stereo Images: Right Image is Captured After Left Image.

It should be noted that the use of stereo cameras in our system simplifies the calibration process since it is performed once and for all in the laboratory, whereas a monocular camera requires calibration for each road scene [3].

Thus, after calibration (2), we used a trigger card to constantly generate an electrical signal that will activate both cameras simultaneously to capture images at the same time [5]. Once the camera is activated, an image of the road scene is captured.

Note that the cameras must be correctly synchronized to obtain adequate results.

We will see in the following paragraph the detail of a stereovision method based on the geometry of the sensor seen previously. Fig. 4 illustrates the important parameters for stereoscopic measurements: S_L and S_R represent two cameras that are at distance B from each other.

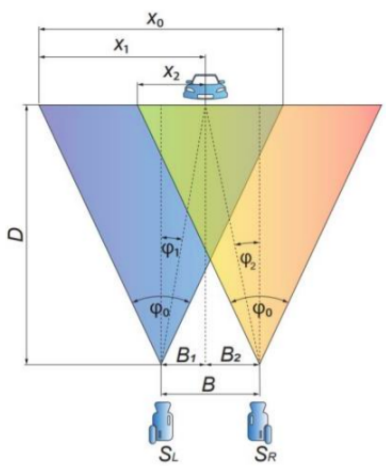

Fig. 4. Parameters for Stereoscopy Measurements. System Placed Horizontally on the Road [6].

φ_0 represents the field of view FoV of the cameras. The distance to the object (in our case a vehicle). D can be expressed by geometrical derivations leading to the following expression (equation 1) [6]:

$$D = \frac{B}{\tan\varphi_1 + \tan\varphi_2} \tag{1}$$

Where:
φ_1 and φ_2 are the angles between the axis of the camera lens and the direction of the object. After further derivation, we arrive at the following expression (equation 2) [6]:

$$D = \frac{B \times X_0}{2\tan\left(\frac{\varphi_0}{2}\right)(X_1 - X_2)} \tag{2}$$

X_0 is the number of horizontal pixels of the images, X_1 and X_2 are the numbers of pixels between the midpoint of the horizontal edge of the bounding box of the object and the left edge of the image (X_1 is for the left image and X_2 for the right one).

Finally, we can estimate the distance to any object appearing in both images if we know the distance between the cameras (B), the number of horizontal pixels of the image (X_0), the FoV of the cameras φ_0 and the horizontal difference between the same object in both images (X_1-X_2) also known as disparity. In fact, the disparity refers to the difference in image location of an object seen by the left and right cameras, resulting from the cameras' horizontal separation [5].

To calculate the actual distance between the stereo system and the vehicle, we need to calculate the angle between the road and the orientation of the system (Fig. 5).

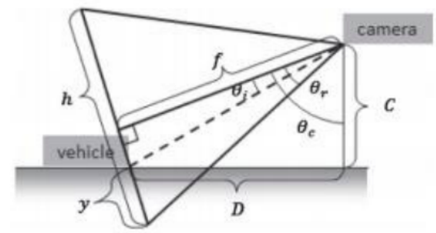

Fig. 5. Parameters for Stereoscopy Measurements. System Placed above the Road [2].

This distance is calculated as follows (equation 3):

$$D = D' \cos(\alpha) \tag{3}$$

Where:
- α: is the angle between the orientation of the system and the road
- D': is the distance between the object and the horizontal plane of the cameras. Then, the proposed method for estimating inter-vehicle distance involves three major steps. The first consists in preparing the two images generated by our stereovision system to detect the vehicles present in each image and to delimit them by bounding boxes [2], [8].

Then, the second step consists in finding the objects that appear respectively in the two images to precisely determine the value of X_1 and X_2 (cf. section 2) [6], [8]. Thus, if a vehicle is detected in the left image, the algorithm will have to search for it in the right image; the following criterion must be perfectly respected. This step is especially the most complicated of the whole algorithm.

The third step of the algorithm consists in calculating the distance between our stereovision system and each vehicle. At this stage, all the necessary parameters are already obtained, and the distance is calculated from the second equation. Finally, we deduce the inter-vehicle distance from the third equation by subtracting the estimated distance between each vehicle and the two cameras.

III. YOLO V3 Deep Neural Network Architecture

The heart of our distance estimation algorithm is the vehicle detection and recognition block, which allows us to locate and delimit vehicles in a stereo image by drawing a bounding box around the vehicles in the image. In this respect, we have opted for a variety of the YOLO Deep Neural Network (YOLOv3) algorithm for vehicle detection and recognition [4,5]. This neural network can recognize several objects in the same image, belonging to the same class or to different classes. In our case of study, we are mainly interested in the third version of the YOLO model, because it has the advantage of being able to run in real time on stereo images/video streams, while keeping a good predictive performance. This version has been developed by Joseph Redmon and researchers at the University of Washington [7].

The YOLOv3 algorithm is an improvement of YOLOv1 and YOLOv2 because it has advantages of high accuracy in detecting, recognizing, and locating objects as well as its speed of execution [7]; it has become a crucial point of current research. However, it still lags the most powerful object detection algorithms in terms of accuracy. Moreover, the principle of the model is to scan the image only once, by passing it through a deep neural network, hence the name YOLO (You Only Look Once) unlike methods based on CNN convolutional or RNN recurrent neural networks [7].

In addition, the latest version of the model has also focused on increasing the number of network layers as well as on the implementation of three scales of bounding boxes to detect smaller objects. These types of algorithms make it more possible to detect overlapping bounding boxes for the same object. The authors therefore apply a method called Non-Max Suppression to keep only the most significant bounding boxes [7]. After implementing and running our model, we obtain as output the bounding box coordinates of all detected vehicles. This information is very useful to obtain the parameters X_1 and X_2 which are used in the mathematical expression of distance estimation by stereovision [6]–[8].

A. Comparison of YOLO with Other Detection Algorithm

In comparison to recognition algorithms, a detection algorithm does not only predict class labels but detects locations of objects as well. So, it not only classifies the image into a category, but it can also detect multiple Objects within an Image [11]. It is extremely fast and accurate. Moreover, you can easily tradeoff between speed and accuracy simply by changing the size of the model, no retraining required [12]. And this Algorithm does not depend on multiple Neural networks. It applies a single Neural network to the Full Image. This network divides the image into regions and predicts bounding boxes and probabilities for each region. These bounding boxes are weighted by the predicted probabilities [11] (Fig. 6).

IV. Literature Review

A. Evolution of Image Recognition

Particularly in recent years, image processing has come a long way. Evolution can be majorly seen in technological fields like computer vision and software. First computer vision and study on images started in 1960s. Before this, image analysis was done manually. The major improvement in deep learning techniques and in image recognition technology took place in 2010. Now it is so advanced that we can write a program for supercomputers to train themselves [13]. In early days, Feature extraction and classification paradigm was followed for object detection. Manually people need to define a specific feature which needs to be identified for extraction. After extraction of features, the objects or those features were represented in vector forms. These vector forms were used for training a model and for detecting an object while testing a model. It was a difficult task for detection of multiple objects since we have to find a general feature which can be found in multiple objects and can fit in different objects for training the model. The disadvantage is choosing the general feature which was a complex task, and the detection accuracy was not that great. In 2012, compared to other models which were already there, CNN gave a satisfactory results and good accuracy. Though there was CNN model developed in 1990s, the accuracy was low due to improper training examples and fragile hardware. CNN model became strong when GPUs were prevailing. The CNN model built in 2012 was trained by the dataset which consists of 1.2 million images and 1000 categories. The experiment conducted by Krizhevsky proved CNN's powerful ability in images classification [13]. CNN methods can build feature filters while training the process which cannot be done in traditional methods. When compared to other models, CNN models are more friendly and have self-learning ability [14]. Because of all these advantages, CNN became a major tool for image classification. To enhance the performance of CNN model,other regression heads were attached to the current model. This regression head is used to predict 4 coordinated after training it separately. Hence CNN allows both classification and regression head. While testing the model both classification and regression works simultaneously. Classification predicts the class score, and Regression helps for positioning. During 2012 to 2015, the experiments conducted were successful in attaching both classification and regression to CNN models Overfeat-Net, VGG-Net and ResNet. The error rate was reduced from 34% to 9% in these experiments. Since multiple object detection was failed in the experiments conducted in 2012, Research in 2014 started conducting experiments to achieve the task of multiple object detection. In a single image more than five objects were to be detected. This can be done only when the system figures out object's class and location of the object. Usually, deep convolution neural network works with the fixed size of image (e.g. 520 x 520). Because of this recognition accuracy might go low for the images and subimages of arbitrary size or scale [15]. To overcome this issue Spatial Pyramid Pooling was introduced in 2014. Fixed length representation regardless image size or scale is achieved by developing a network structure called SPP-net. By removing the size or restriction, accuracy of the convolution neural network can be achieved. In SPP-net feature maps are computed only once to generate fixed length representations to train the detectors by pool features in the sub-images. Repetition of computation of convolution features can be avoided by this method. This method was better than R-CNN and it gave satisfactory accuracy. Most of the ideas regarding CNN approach and classification came out in 2014. The main idea was to perform classification on every region that possibly contains objects. The region proposals and classification approaches achieved high accuracy and precision. But these region proposals take a very long time to process which makes the speed of the entire system to go low. Because of this timeconsuming limitation, the region proposal approaches cannot be deployed in applications which are time critical like autodriving, surveillance systems etc. Recently, YOLO (You Look Only Once) a unified object detection model was proposed by Joseph [7]. Frame Detection in YOLO is considered as regression problem. It is a pretrained model which does not require a dataset to train the model. It consists of weights and object detection is done as boxes. The image which is inputted is regressed to tensor from the model directly which signifies the digit of every object's position and class score of the object. The images which are inputted need not go through the YOLO network more than once. Because of this, processing of images is faster in this model. When compared to other object detection models, Yolo has

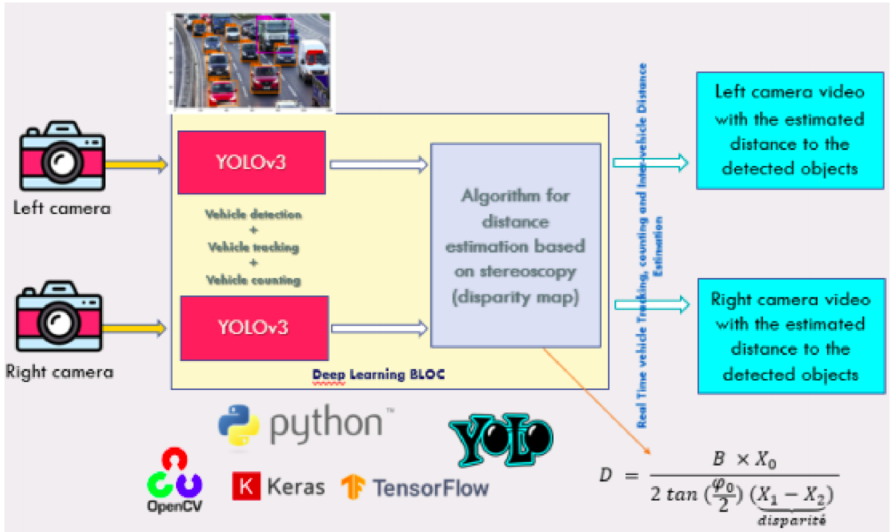

Fig. 6. Two-Camera/ YOLO Real Time System. Algorithm Architecture.

accomplished more than 50 times better accuracy. So currently YOLO is one of the best choices for real time object detections [7].

B. CNN based Object Detection: Benchmarking

1) R-CNN: R-CNN stands for Region-based Convolution Neural Network. It combines region proposals with Convolution Neural Networks (CNN). R-CNN aids in focusing objects with deep neural network. It trains a model of high capacity with fewer amounts of annotated detection data. To categorize the object proposals deep convolution network is used and due to this RCNN attains outstanding accuracy for object detection. Ability of R-CNN is high because numerous object classes can be scaled without resorting to estimated methods together with hashing [16]. The researchers projected a multi stages purpose followed by classification. And classification was done using regions paradigm. The three main components of the developed system is feature vector extraction by CNN, classifier used which is Support Vector Machine and the last one is region proposal component [17]. Feature vectors extracted from CNN are used to train the SVM classifier. Training is done on two datasets where CNN supervised is trained on one large dataset (ILSVRC) and one small dataset (PASCAL). During the testing time, the region proposal component used in this experiment is Selective Search. 2000 fixed size category independent regions which contain objects is produced by Selective Search [14]. SVM is used fot domain specific classification after a completely trained extractor of CNN converts every potential vector into feature vectors. The two main problems that may arise are intersection-overunion (IOU) and duplicate detections.

IOU will overlay the higher scoring region. These problems are eliminated by greedy non maximum suppression and refining the bounding box by using a linear regression model at the end. Satisfying accuracy for detection was accomplished by RCN when compared to any other detecting methods found in 2014. But RCNN also has many drawbacks because of complex multi-stage pipeline. The main role of CNN is to act as a classifier. The region prediction is totally depended on exterior region proposal methods. This slows down the whole system while both training and detecting objects. Since RCNN has a separate training manner for every component which results in CNN, it is very difficult for optimization. Besides, CNN cannot be updated during the training of SVM classifier [14].

2) SSD: Single deep neural network is used for detecting the objects in images by Single Shot Detector (SSD). The output spaces of bounding boxes are varied in SSD method. These boxes are set of default boxes over different aspect ratios. The approach is scaled to every feature map location after it varies. The predictions from multiple feature maps are combined in Single shot detector. Multiple feature maps are combined to handle objects of different sizes naturally. Some of the benefits of SSD are SSD totally removes the proposal generation. The following pixels or feature resampling stages are also eliminated which encapsulates every computation in a single network. Training in SSD is easy when compared to other models and it is forthright to assimilate into systems which needs a detection component. SSD accuracy can be increased by adding an additional method for object proposals. Since it is combined with other models, the training and inference is much faster.

3) R-FCNN: R-FCNN stands for region-based, fully convolutional networks. It is a simple framework used for efficient and accurate object detection. The other region-based network detectors like FCNN and Faster RCNN [18], are based on per region sub network. But R-FCNN is entirely convolutional with every computation shared on the whole image. There is a predicament between image classification and object detection. Image classification has translation invariance issues and object detection has translation variance issues. To overcome this issue positive sensitive score maps are proposed. Thus, region based fully conventional network can accept fully conventional image classifier like latest residual networks for detection of object [14]. PASCAL VOC datasets are used to show the modest results. ResNet with 101-layer is used. The results achieved by RFCNN are 20x better and faster than faster RCNN while both inference and training

4) Faster R-CNN: Faster region-based convolution neural network is similar to RCNN which is an object detection algorithm. The features are extracted from the input image through convolution layers. Region proposal network (RPN) is used in Faster RCNN which shares the convolution features for each spatial location like objectness classification and bounding box regressor. The FRCNN network is cost effective than RCNN. It basically predicts the object boundaries and objectness scores for every position of the object. High quality region proposals are created, and end-to-end training is done then this technique is used by Fast RCNN method for object detection. When compared to other object detection methods, faster region-based convolution neural network has less running time for detection of object. When feature maps are sent into RPN, feature maps projected region proposals are extracted. RoI pooling is done on feature maps. The result of Faster RCNN classification will be multiclass classification and bounding box regressor for each RoI [18].

5) Fast R-CNN: Fast RCNN stands for Fast Region Based Convolution network. It is a training algorithm for detection of objects. Fast RCNN is better than RCNN and SPP net as it resolves almost all disadvantages and increases the speed and accuracy of RCNN and SPP net. When compared to RCNN and SPP net, Fast RCNN has higher detection quality that is mAP. Training in Fast RCNN is done in single stage by means of multi-task loss. All the network layers can be updated during the training process. Disk storage is not utilized for feature caching by fast RCNN. The Convolution feature map is of Deep Convolution Network and RoI projection. The RoI pooling layer is extracted from the convolution feature map in RoI feature vector. RoI feature vector is extracted for each RoI.The output will be softmax and bbox regressor [11]. This paper proposes a Fast Region-based Convolutional Network method (Fast R-CNN) for object detection [18]. By using the work of algorithms which are built previously, fast RCNN uses deep convolution network to classify object proposals efficiently. This helps Fast RCNN to achieve better detection accuracy and increase training and test speed. The training done by fast RCNN on deep VGG16 network is 9x faster than RCNN and 213 x faster when compared to the test time. A good mAP on PASCAL VOC 2012 is achieved. When Fast RCNN is equated with SPPnet, test accuracy is 10x faster and accurate and training of VGG16 is 3x times faster than SPPnet. Because of the detailed work carried out in this experiment, new insights are provided. The improved detector quality is achieved at the end. The main issue with other object detection algorithms is they are too expensive in time analyze in the past.

6) SPP-net: CNN models work only with the fixed size of input image like 520x520. Because of this the recognition accuracy will go low. To overcome the above-mentioned issue Spatial Pyramid Pooling was equipped. The fixed length of symbolization irrespective of size or scale can be generated by a Spatial Pyramid Pooling (SPP-net) network structure. Object deformation can be achieved by Spatial Pyramid Pooling. When compared all CNN based methods, Spatial Pyramid Pooling is an improved structure. Feature maps for the whole image can be computed at once in Spatial Pyramid Pooling method. Pool features in sub images of fixed length is also computed to train the detectors. In the other methods, convolution featured are repeatedly computed which can be overcome in Spatial Pyramid Pooling. SPP-net is more weighted in object detection. When compared to RCNN method, SPP-net is 30-170× faster and when both the models were tested on Pascal VOC 2007, SPP-net gave better accuracy than RCNN.

C. Real Time Objects Detection and Tracking: Benchmarking

Moving object detection and tracking is presented in [16]. Intuitive graphic interphase is achieved by means of new algorithm during the extraction of Silhouette. For the fast detection following algorithms were combined, frame difference method, background subtraction method, Laplace filter and Canny edge detector. The multivision dataset is used for testing the sequence images. The better performance object tracking algorithm is proposed. The detection algorithms and basic operation techniques are integrated, and graphic user interface is used to make the process simple and straight forward. World is adapting to artificial intelligence from past few years with influence of deep learning. Many object detection algorithms have been compared like Region-based Convolutional Neural Networks (RCNN), Faster RCNN, Single Shot Detector (SSD) and You Only Look Once (YOLO). And the result id faster RCNN and SSD gives better accuracy with Yolo. Efficient implementation and tracking are done by combining deep learning with SSD and mobile nets. SSD helps in detecting the object and tracking them in a video sequence. They achieved in enabling good security utility for enterprise and order. The model created can be deployed in drones, detect attacks and CCTV cameras in government offices, colleges, hospitals etc. Distance and estimation of real time video is achieved in [10]. Combinations of two deep learning models are developed to achieve object detection and tracking. The algorithms are tested on both railway and environment. Monodepth algorithm is applied for the estimation of object distance. Stereo image dataset and monocular images are used to train the model. Testing of both the models is done on another two datasets. They are Cityscape and KITTI datasets. Pedestrian and vehicle behavior tracking is done by developing a new method-based SSD. The new SSD algorithm is developed by the coordinates of the output bounding boxes of SSD algorithm. The whole development is tested on the real time data and the main objective is to monitor the tracks of pedestrians and vehicles to make sure it does not lead to any dangerous situations. Real time video of Routen tramway is taken by embedded cameras.

D. YOLO Model

YOLO (You Look Only Once) a unified object detection model was proposed [7]. Detection in YOLO is considered as regression problem. It is a pre trained model which does not require a dataset to train the model. It consists of weights and object detection is done as boxes. The image which is inputted is regressed to tensor from the model directly which signifies the digit of every object's position and class score of the object. The images which are inputted need not go through the YOLO network more than once. Because of this, processing of images is faster in this model. When compared to other object detection models, Yolo has accomplished more than 50 times better accuracy. So currently YOLO is one of the best choices for real time object detections. The base YOLO model can process real time images up to 45 frames per second whereas Fast YOLO processes can process nearly 155 frames per second. The base version is the smaller version of the network. The natural images can be generalized very well using this model. According to recent studies, YOLO is one of the fastest detecting models when compared to other CNN object detection models [7] (Fig. 7).

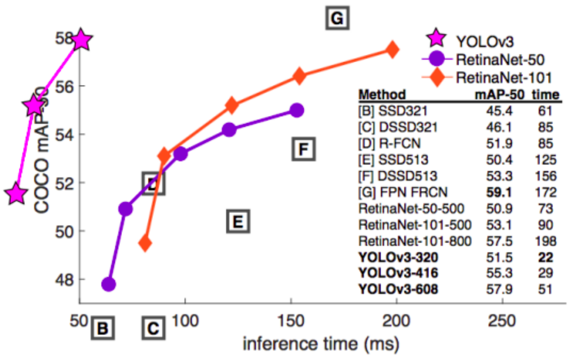

Fig. 7. Comparison to Other Detectors [7].

E. Kalman Tracking

In recent decades real time object tracking has been applied in multiple areas like human computer interaction, security, surveillance, video communication, etc. Object tracking is the process of locating one or multiple moving objects in the scene during continuous time. Some of the challenges faced are, Initial moving object segmenting. The goal of segmentation is to simplify or change the representation of the image into something that is more minimal and easier to analyze [12]. Rapid appearance changes are caused by image noise, illumination changes, non-rigid motion, and different poses. Tracking the moving target is complex in background. When tracking an object in real world background can be quite complicated for various depths in the background which can interfere their tracking. So Kalman filter was introduced which is also called as linear quadratic estimation. It is an algorithm which uses the series of observing measurements over time [13].

There are two main parts that contributes in Kalman tracking. They are Prediction and correction. Prediction will predict the project current state and estimate the next state. If there is any mistake in prediction, it goes to correction. In correction, Kalman gain is computed. The system state is updated after Kalman gain is found and error covariance is also updated. Correction is in turn connected to prediction. The detecting range can be predicted by Kalman filter in order to accurately track object in occlusion which means a complicated background [12].

F. Unified Detection Model: YOLO

Earlier detection models repurpose the classifiers to achieve detection. The model is applied to many location and scales in the image. If there is a maximum scoring region on the image, then it is detected. But YOLO has an entirely dissimilar technique. A single neural network is applied to a whole image. In Yolo model, network spits the image into regions. After the splitting, bounding boxes and probabilities for each region is predicted. The predicted probabilities help to weigh the bounding boxes [15]. When compared to classifier-based methods, YOLO has several advantages. The predictions are made by the global context in an image because Yolo takes whole image for the testing. RCNN requires thousands of predictions for a single image. But in YOLO the predictions are made by the single neural network assessment. Because of this yolo is tremendously fast. It is 1000 x times faster than RCNN and 100 x times faster than Fast RCNN. Thus, Training of YOLO model can be done in two ways. One can either use their own dataset to train the model or can use the pre-trained weights. These pretrained weights are available for public use.

Some of the dependencies required to build a YOLO in Tensorflow:

- Tensorflow/Keras (GPU version preferred for Deep Learning)
- NumPy (for Numeric Computation)
- OpenCv (for Image Processing)
- IPython (for displaying images)
- Glob (for finding pathname of all the files)

Anaconda is suggested as it contains many libraries of machine learning and deep learning and interaction with Spyder, and Jupiter are easier.

V. Methodology

A. Object Detection

There are mainly two ways of object detection. First one is to take object images and train our own Machine Learning model. When we train the machine learning model, main input is features. Based on the features, the model will learn and create weights for that object. But there are some disadvantages in this method. For example, when we consider the object as car, there are different types of cars based on their shapes. Sometimes even a truck might look like a car in the video. To overcome this issue, the feature extraction must be very much robust. Like the model should be trained by all the aspects like size, dimension, and shape. This requires a large Data. Because of this training will depend on our system. If the system's GPU is low, then we cannot train our model at all or it might take a very long time to process. If we go for SVM, neural networks or Random Forest models or any basic type of modeling which takes less amount of data, it does not work with the real time data. So, we use a YOLO model which can be defined by a concept of convolution neural network. The one difference between YOLO and other CNN models are, YOLO has a moving or floating window. That means a window is created in YOLO which keeps moving from left to right. While moving if any object which is needed occurs on the screen, YOLO will highlight that object. With the weights which are already present in the model, it will try to detect the object and recognize it. For each object there exists a different weight in YOLO. There are different types of YOLO. Some models may have 150 different objects, and some might have 80. There is an option to limit the number of objects to whatever is required, or one can use all the objects present in the model. In this research we have used a model with 80 weights. Every time the code runs, we have to load the weights. Since we do not want our model to detect all 80 weights or objects, we limit the weights for first 10. This is how detection of object takes place in YOLO.

B. Object Tracking

TensorFlow used can help to detect the object but it will not track the object. To track the object, bounding box is given to all the objects present in the video or on the screen. TensorFlow gives the kernel dimension of the weights. Out of eight coordinates in kernel dimension we extract four coordinates. We will multiply the width and height of the coordinates of the kernel dimension because to fix the dimension of the object with is detected

C. Distance Calculation

Distance is calculated by the bounding boxes. In fact, Yolo detect the objects of interest and give their regions. Next, it takes the left and right images and construct a dense disparity map. Finally, it takes different regions of the objects and work out an average disparity value to then work out a distance using the focal length and camera baseline of the stereo capture device.

In addition, the movement when other object is completely detected, the size becomes bigger. If the portion of the object detected is less, then we can assume that either the object is far from us or it is in the sideways like left or right. The bigger the size, the closer the vehicle or object is. And the smaller the vehicle, the distance is more. So, from the bounding box distance is calculated. We are taking some constant and we are predicting the distance.

Then, we display on the screen the estimated inter-vehicle distances each time a vehicle crosses the delimited area.

D. Architecture of our System

Before any experimentation could occur, a baseline system needed to be created. We began by stripping the given yolo.py to its main functions and modularizing it for use on individual frames. We then used parts of the given stereo_disparity.py to develop two functions for dense disparity distance calculation. First, yolo would detect the objects of interest and give their regions. Next, it would take the left and right images and construct a dense disparity map. Finally, it would take different regions of the objects and work out an average disparity value to then work out a distance using the focal length and camera baseline of the stereo capture device. Once we had this basic system working, we could begin to experiment with different techniques of optimization.

The first thing we noticed was that many of the images had a low contrast. To remedy this, we used a form of histogram equalization called Contrast Limited Adaptive Histogram Equalization (CLAHE) which works by taking small regions (tiles) and applying equalization on those, rather than the entire image. Whilst the filter did not seem to have much effect on distance values, it had some success in helping yolo detect objects in poor light conditions.

The next experiment was to apply a filter to the disparity map. The filter we tried was the Weighted Least Squares (WLS) filter. The WLS filter smooths the disparity map and makes it more uniform. This seems like it should help with the distance calculation though, in practice, not much change was seen and in some cases the filter made things worse. This could be because smoothing causes the image to lose detail and thus lose valuable information that could have helped with distancing. We also apply a noise filter to the disparity map to lower the amount of noise as this would help to provide a better distance average.

In summary, we have experimented with various techniques to attempt to increase the robustness of the system. Whilst not all of these have proved effective, they have all lead to a solution that is a suitable prototype for object distance detection. YOLO has been able to find most of the objects in the scene (helped a little by CLAHE histogram equalization) and the disparity maps seem to have given enough information to get a reasonable distance estimate.

Moreover, the results are assumed to be accurate when the model detects the objects correctly.

During the validation of objects detected by the model, we have got the object accuracy of 84.89% for 0.031 seconds per image of processing (Fig. 8).

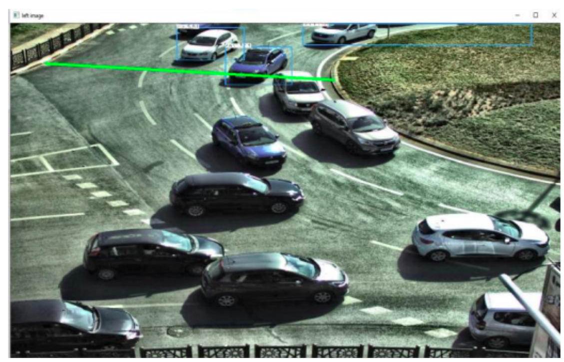

Fig. 8. Execution of the Algorithm.

VI. Conclusion

When we analyze the results, we have got for precision and recall, it can be said that YOLO is one of the best models used in detection of vehicles. YOLO model has achieved 85% of precision with 62% of recall with the time rate of 30 frames per second. We have also successfully found the distance between the vehicles.

The YOLO model is in the top place in the object detection speed when compared to other convolution neural networks. The detection speed that we have achieved is 0.03 seconds per image, which is 10 times faster than the already present object detection models. The YOLO model is the only model that has achieved this accuracy in real-time video streaming. From the computation of orientation estimation, we have found that YOLO has a good precision in prediction of object orientation. By all the experiments conducted, it is proved that performance of YOLO is high in both object detection and orientation precision. Since object's orientation has a main role in intelligent transport systems, with the accuracy we got for orientation estimation we can state that YOLO fits in the best for them. We have also successfully found the distance between the vehicles.

A. Implementation of our System in Real World

Layer 1: *Acquisition and pre-treatment*
The main function of this layer is to ensure the acquisition of images from a stereoscopic system. Then, there is image processing which consists in improving the quality of the image by removing noise, camera vibrations, lighting changes, etc.

Layer 2: *Attribute extraction and analysis*
From the images obtained from Layer 1, this layer extracts the static and dynamic attributes of the vehicles necessary for road traffic management: vehicle detection, trajectory extraction, vehicle recognition (license plate, mark, and color detection), and the measurement of inter-vehicle distance. Then, the extracted attributes are analyzed to understand traffic conditions and behaviors.

Layer 3: *Detection of illegal activities and anomalies and analysis of traffic flows*
Based on the results of the previous layers, this layer provides services for efficient management and control of road traffic. It can detect traffic violations (such as stop violations, red light violations, speeding, overtaking, fake license plate, unauthorized change of direction, etc.) and anomalies on the road (accidents, obstacles blocking traffic, traffic light malfunction, etc.).

B. Future Work

In this paper, we present a method of inter-vehicular distance estimation based on stereoscopic vision. Indeed, after detecting, locating, and delimiting vehicles using the YOLO V3 Deep Neural Network algorithm, we estimate the distance separating a vehicle from the cameras based on stereo vision principles to finally deduce the inter-vehicular distance. As a perspective, we plan to extend the technique to estimate the inter-vehicle distance in urban areas, we aim to satisfy the real-time constraint to be able to deploy our system in the real world.

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Blind, Secured and Robust Watermarking for 3-D Polygon Mesh using Vertex Curvature

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***Abstract*—In this paper a blind, imperceptible, robust and secure watermarking scheme for 3-D mesh models is presented. Here, the watermark is embedded in deeper surface vertices to minimize the perceivable distortion. Deeper surface vertices are selected on the basis of their mean curvature (lesser than zero) and converted to spherical coordinates. Out of the three spherical coordinates, radial distance represents approximate mesh and is invariant to distortionless attack. Therefore, watermark bits are embedded by modifying the distribution of radial distance to make the proposed scheme robust against such attacks. Radial distances are divided into bins and normalized to range in [0, 1]. Each bin accommodates one watermark bit. Watermark is embedded repeatedly in the 3-D mesh to resist cropping and simplification attack. To ensure higher security, a 128-bit unique watermark is generated by hashing (MD5 algorithm) the mean of histogram map obtained from a grayscale watermark image. Watermark bits are extracted from bins by comparing mean of each bin with a reference value. Since original mesh is not required at the time of extraction, the proposed scheme is blind. Through experimental results, it is demonstrate that the proposed scheme has good visual masking and higher robustness against various attacks. It shows improved performance as compared to some of the prominent schemes.**

***Keywords*—3-D mesh watermarking; mean curvature; radial distance; spherical coordinates; visual masking**

I. INTRODUCTION

In the past few decades there has been extensive growth in the use of 3-D objects in virtual reality, video games, animation, medical sciences, industries, and computer aided design (CAD), architecture, archaeology and scientific data visualization [1]. With the increasing accessibility and wide distribution of 3-D objects, the concern for its copyright protection has also increased. Digital watermarking is considered as a potential solution for copyright protection of various multimedia contents [2]. Therefore, researchers are exploring 3-D watermarking techniques for the copyright protection of 3-D mesh objects. Lot of research has been done in audio, image and video watermarking in spatial as well as transform domain. But, the watermarking schemes developed for other multimedia contents cannot be readily used for 3-D mesh due to lack of unique representation. 3-D objects are generally represented by polygonal meshes. Fig. 1 shows 3-D bunny model represented by triangular polygon mesh. 3-D mesh has three basic elements: vertices, edges, and faces [3]. Vertex is the co-ordinate in 3-D space. Edges are connectivity between two vertices. Face describes connectivity of vertices to form smallest unit of 3-D mesh. There is no well defined order and connectivity of vertices, which makes watermark extraction very difficult. Moreover, number of vertices where watermark bits can be inserted are limited as compared to other multimedia content. Due these challenges, 3-D mesh watermarking is still in its infancy [4].

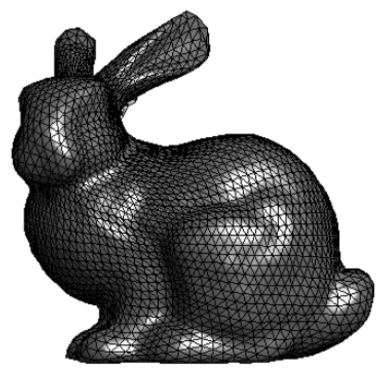

Fig. 1. 3-D Mesh of Bunny.

There are different classifications for 3-D mesh watermarking techniques [5]. According to the insertion space it is classified into spatial and transform domain. In spatial domain, the watermark is inserted directly by altering the coordinates of the mesh vertices. But, in the transform domain watermark is inserted by altering the transform coefficients. Spatial techniques provide higher imperceptibility but are less robust. Some robust spatial watermarking schemes have been reported in [6]– [8]. But, the main drawback of these schemes is that they are relatively less robust to connectivity attacks. Whereas, transform domain techniques are robust but has higher computational time. Watermarking techniques can also be classified into non-blind and blind depending on whether the original host is required or not at the time of extraction. Non-blind schemes require original mesh during watermark extraction in contrast to blind schemes. Generally, non-blind techniques are more robust than blind techniques. Whereas blind schemes have high capacity, and can be easily implemented. But, practical applications prevent access to the original 3-D model during extraction. Considering pros and cons of different types of watermarking schemes, robust blind watermarking schemes in spatial domain are more feasible for practical applications. The majority of the exisiting 3D watermarking schemes suffers with low imperceptibility, robustness , security and high computational cost. For real time applications the computational cost is assumed to be low. Hence there is need to develop more blind and robust schemes for 3-D watermarking. In this paper a blind and robust 3-D watermarking scheme is presented which is robust to majority of attacks and maintains high imperceptibility. The rest of paper has following organization: Related work is reviewed in Section 2. The proposed 3-D watermarking scheme is described in detail in Section 3. Section 4 presents the experimental result and discussion. Section 5 concludes the paper.

II. Related Work

Various 3-D mesh watermarking schemes have been proposed till date but still this field is in its infancy as compared to the development in image, audio and video watermarking. The two main hurdles in handling 3-D mesh watermarking are: lack of an ordered structure precludes systematic analysis of model and difficulty in anticipating all the attacks due to various mesh manipulation graphic tools. In spite of these challenges, researchers have put persistent efforts to propose various blind and non-blind 3-D mesh watermarking approaches for improving imperceptibility, robustness and payload.

In this direction, a blind scheme is proposed by Nakazawa et al. [9]. It uses mesh saliency based on the surface curvature to segment the triangular 3-D mesh. Then watermark bits are inserted in the regions by modulating the vertex norms. A similar approach is suggested by Zhan et al. [10] where watermark bits are interleaved in vertex bins formed on the basis of vertex curvature. Authors assert that this method has higher robustness and imperceptibility than the schemes proposed in [11], [12]. Li et al. [13] suggested to form bins of eigen values (distance between vertices to the model centre) based on improved vertex grouping. It uses piecewise mapping function to insert watermark bits in bins. It shows superior performance than [11]. Another blind scheme is proposed by Bata et al. [14] based on sparse QIM and run- length modulated LDPC. This scheme provides higher imperceptibility and lower BER in extracted watermark. Alaa et al. [15] proposed a blind scheme based on vertex distribution and skewness measure. Skewness measure is altered to embed the watermark. Authors claim that the scheme has good visual masking and resistant to a variety of common attacks. Recently, Sharma and Panda [7] have proposed a blind scheme and attempted to fulfil all the watermarking requirements by exploring Local curvature estimation and statistical characteristics for hiding watermark. Medimegh et al. [16] proposed a statistical 3-D watermarking scheme explored invariance property of salient points. They embedded statistical signature at different regions self-segmented around salient points. Hamid et al. [17] have proposed to a blind watermarking method in transform domain, where watermark is embedded in quantified wavelet coefficients using QIM based on 3-D mesh saliency. Though the scheme achieves good imperceptibility and robustness but, it is not robust against cropping attack. Other blind schemes has been reported in [18]– [21]. Some of the non-blind watermarking schemes are proposed in [22]– [25]. Although non-blind schemes exhibit satisfactory robustness but, mostly practical applications prevents having access to the original 3-D model during extraction. Thus, blind schemes are practically more feasible. From the literature review it is observed that the existing schemes are robust to either one or the other set of attacks. Majority of existing schemes have focused on achieving higher imperceptibility and robustness but have overlooked an important watermarking characteristics i.e. security. A comprehensive comparision of the related wok is shown in Table I.

Motivation and contribution of the proposed work From the literature survey, we have observed that there is prospect to develop blind 3D watermarking scheme which is robust to majority of attacks, has higher imperceptibility and security. For practical application of the scheme it should be computationally inexpensive. Motivated by these issues we propose a 3-D watermarking scheme having following contribution:

- **Improved robustness:** the proposed blind scheme withstands majority of common attacks like smoothing, additive noise, similarity transformation, quantization, cropping and simplification as evident from experimental results. It successfully survives Meshbenchmark attacks. The proposed scheme has higher robustness as compared to the existing popular schemes in [10], [13], [17]. Although robustness of the proposed scheme against noise attack is not at par with [10], [13], [17] scheme but has acceptable correlation values as discussed in section IV.
- **Improved visual quality:** watermark embedding in deeper vertices of 3-D mesh surface induces less perceivable distortion than the vertices of flat or peak surface [26]. Making use of this observation, in the proposed scheme we select deeper surface vertices for embedding watermark bits to minimize induced distortion. Deeper surface vertices are classified on the basis of mean curvature (C_m) [26]. Proposed scheme offers superior visual masking effect than schemes proposed in [10], [13], [17].
- **Enhanced security:** To enhance the watermark security, a 128-bit binary chaotic watermark sequnce is embedded in the 3-D model. This sequence is generated from a grayscale watermark image/logo. Mean of histogram map of the grayscale watermark image is calculated. Then the mean is hashed by using MD5 hash algorithm to obtain the watermark sequence. Watermark sequence is highly sensitive to the change in watermark image pixels, thus ensures high watermark security.
- **Low computational cost:** The proposed scheme embeds in spatial domain therefore it is less computationally expensive. The proposed embedding scheme has linear time complexity as discussed further in section IV.C.

III. Proposed Watermarking Scheme

The proposed 3-D mesh watermarking scheme is based on modulation of radial distance distribution. Proposed scheme consists of three modules i.e. watermark generation, embedding and extraction, explained in detail in the following subsections.

TABLE I. COMPARATIVE STUDY OF 3-D WATERMARKING SCHEMES(SM-SMOOTHING, SP-SIMPLIFICATION, SD-SUBDIVISION, CP-CROPPING)

Method	Domain	Robustness against attacks					Blind	Capacity
		Geometric		Connective				
		SM	Noise	SP	SD	CP		
Jing et al. [24]	Spatial	Yes	Yes	$\leq$ 5%	No	Yes	No	-
Song Li et al. [13]	Spatial	Yes	Yes	NO	Yes	No	Yes	64 bits
Cho et al. [11]	Spatial	No	yes	$\leq$90%	Yes	No	yes	64 bits
Garg and Agrawal [22]	Spatial	No	Yes	$<$70%	Yes	No	No	256 bits
Seung et. al. [19]	Spatial	Yes	Yes	$\leq$30%	No	Yes	Yes	16 bits
Alaa et. al. [15]	Spatial	No	Yes	$\leq$70%	No	Yes	Yes	32 bits
Zhan et al. [10]	Spatial	Yes	yes	$\leq$90%	No	No	Yes	Variable
Hamidi [17]	Spectral	Yes	Yes	$\leq$70%	No	No	Yes	64 bits
Feng et. al [18]	Spectral	Yes	Yes	No	No	Yes	Yes	36 bits
Proposed	Spatial	Yes	Yes	$\leq$50%	No	yes	Yes	128 bits

A. Watermark Generation

In the proposed scheme, to ensure higher security a unique 128-bit binary chaotic watermark sequence is generated according to the grayscale watermark/logo image of size $M \times M$. Firstly, a histogram map (HM) of grayscale watermark is generated. Then the mean of HM is calculated which is further used to generate an intermediate key. The resulting key is hashed by the hash function MD5 to obtain a 128-bit random binary sequence. This sequence is embedded in the 3-D model. Other hash algorithms like SHA can also be used for hashing, but its computation time and security should be taken into account. Watermark sequence is highly secure as the secret key is highly sensitive to the minor alteration in the watermark pixels. The watermark sequence can resist brute force attack. During extraction, the authorised user can obtain the secrete key according to the valid watermark image/logo provided for validation. Following are the steps for watermark generation:

Step 1: Generate the histogram map from the grayscale watermark image using transform function as follows:

$$HM = \sum_{c=1}^{M} (Histpw_c || Pw_c), \forall Pw[0, 255] \quad (1)$$

where $Histpw$ is the frequency of a pixel pw in watermark image.

Step 2: Generate intermediate key (8-bits of binary key sequence) from the HM as:

$$Transformfunc = \sum_{c=1}^{M} dec(HM_c) \ mod \ 2 \times 2^{14} \quad (2)$$

$$intermediatekey = mean(Transformfun) \quad (3)$$

where dec is decimal equivalent of HM.

Step 3: The resulting $intermediatekey$ (8-bits) is hashed by MD5 hash function. A 128-bits binary sequence (W) is generated by hashing. W is used as a binary watermark sequence for embedding.

B. Watermark Embedding

Proposed watermark embedding scheme is based on the modulation of radial distance (ρ) distribution in the deeper surface of mesh to reduce perceivable distortion and achieve higher robustness. Deeper surface vertices are selected on the basis of C_m . Vertices with $C_m < 0$ are deeper vertices. Fig.2 shows grayscale representation of C_m for bunny model, the darker area represents deeper vertices ($C_m < 0$) used for inserting the watermark , and the lighter area shows superficial vertices ($C_m > 0$).

Fig. 2. Grayscale Representation of Mean Curvature in Bunny 3-D Model.

Selected vertices are converted from Cartesian coordinate to spherical coordinate (ρ, θ and φ), shown in Fig. 3. Watermark is embedded by modulating ρ_i as it is invariant to similarity and reordering transforms and represents approximately the mesh shape. Embedding in spherical coordinate particularly in ρ is more robust than coordinates (x, y, z). Radial distances of selected vertices are divided into bins and normalized to range [0,1]. One watermark bit is embedded in each bin by modulating radial distance using histogram mapping function as suggested in [11]. Watermark is embedded repeatedly to sustain attacks like simplification and cropping attack. Fig. 4 shows the block diagram of embedding process. Detailed steps for watermark embedding process are provided below.

Steps of watermark embedding process

Step 1: *Vertex selection*
Deeper surface vertices are selected for embedding having mean curvature less than zero. Mean curvature (C_m) of vertices are calculated using method suggested by M. Mayer et al. [27]. C_m is calculated using following equation.

$$C_m = (\sum_{i=1}^{n} \theta(v_{i,j}))/\frac{1}{3}\sum_{k=1}^{n2} A_k \quad (4)$$

θ $(v_{i,j})$ denotes the angles between the normal of the two adjacent triangles, and A_k(k=1,2,...,n2)

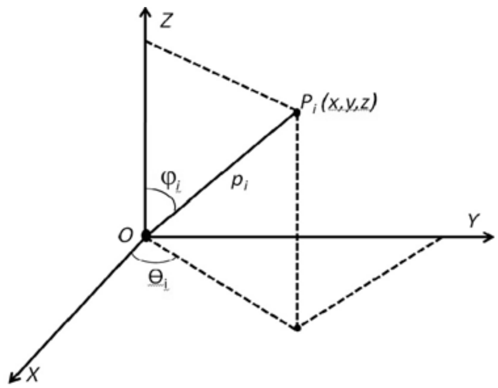

Fig. 3. Spherical Coordinates.

denotes the triangle area corresponding to the 1-ring neighborhood of vertex. Vertex having $C_m < 0$ are selected for embedding.

Step 2: *Convert Cartesian coordinates to spherical coordinates*
Cartesian coordinates of selected vertices v_i are converted into spherical coordinates (ρ_i, θ_i and φ_i) using given equations:

$$\rho_i = ((x_i - x_g)^2 + (y_i - y_g)^2 + (z_i - z_g)^2)^{1/2} \quad (5)$$

$$\theta_i = tan^{-1}((y_i - y_g)^2/(x_i - x_g)^2) \quad (6)$$

$$\varphi_i = cos^{-1}((z_i - z_g)/\rho_i) \quad (7)$$

where i is the i^{th} selected vertex and (x_g, y_g, z_g) are the mean value of all vertices of 3-D model. For the proposed embedding scheme only radial distance (ρ_i) of selected vertices are modified while keeping the other two coordinates i.e. φ_i and θ_i unaltered.

Step 3: *Bin formation*
Bins are formed by dividing ρ_i having equal range with respect to their values. One watermark bit is embedded in each bin. As watermark is embedded repeatedly, number of bins N is according to the watermark length L and number of repetitions. Bins are divided by using following equations:

$$\begin{aligned} B_n = \{\rho_{n,j} | \rho_{min} \\ + ((\rho_{max} - \rho_{min})/N).n < \rho_i < \rho_{min} \\ + ((\rho_{max} - \rho_{min})/N).(n+1)\} \end{aligned} \quad (8)$$

where 0≤n≤N-1, 0≤i≤number of selected vertices, 0≤j≤ M_n-1, M_n is the number of radial distance of n^{th} bin and $\rho_{n,j}$ is the j^{th} radial distance of n^{th} bin. ρ_{max} and ρ_{min} are the maximum and minimum radial distance of the selected vertices in the mesh model.

Step 4: *Bin normalization*
Radial distances in the n^{th} bin are normalized in the range of [0,1] using following equation:

$$\begin{aligned} \grave{\rho_{n,j}} = (\rho_{n,j} - min_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\}) \\ /(max_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\} - min_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\}) \end{aligned} \quad (9)$$

where $\grave{\rho_{n,j}}$ is the normalized value of $\rho_{n,j}$, maximum and minimum radial distance of n^{th} bin is represented by $max_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\}$ and $min_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\}$ respectively.

Step 5: *Watermark embedding*
One watermark bit is inserted per bin by transforming the radial distances using histogram mapping function as suggested in [11]. The mapping function is defined as Eq 10.

$$Y = X^\beta \quad for \quad 0 < \beta < \infty \quad \beta\epsilon\Re \quad (10)$$

Where Y is the transformed variable and the parameter β is a real value. Watermark bit '1', is embeded by transforming ρ to shift the mean by a factor β and for watermark bit '0' shift mean by factor $-\beta$. Mean of every bin μ_n is shifted by following:

$$\mu_n = \begin{cases} \frac{1}{2} + \alpha & if\ W = 1 \\ \frac{1}{2} - \alpha & if\ W = 0 \end{cases} \quad (11)$$

where α is the watermarking strength to determine robustness and imperceptibility. Mean is shifted by transforming each radial distance using Eq. 10. An iterative algorithm is used to determine the value of parameter β such that the value of modified radial distance exists within the range otherwise it may lead to serious distortions. Algorithm 1. shows the iterative process for determining the value of β and embed watermark bits.

Step 6: *Inverse Normalization*
Transformed values of every bin are converted back to original range using following equation:

$$\begin{aligned} \rho''_{n,j} = (\rho'_{n,j}(max_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\} \\ - min_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\}) \\ + min_{\rho_{n,j}\epsilon B_n}\{\rho_{n,j}\}) \end{aligned} \quad (12)$$

Step 7: *Conversion of spherical coordinates Cartesian to coordinates:*
After completing embedding process, arrange and combine all the bins and convert spherical coordinates to Cartesian coordinates using following relation:

$$x_i{}' = \rho_i{}' cos\theta_i sin\varphi_i + x_g \quad (13)$$

$$y_i{}' = \rho_i{}' sin\theta_i sin\varphi_i + y_g \quad (14)$$

$$z_i{}' = \rho_i{}' cos\varphi_i + z_g \quad (15)$$

where $(x_i{}', y_i{}', y_i{}')$ is the vertex Cartesian coordinate of watermarked model and $\rho_i{}'$ is the watermarked radial distance. θ_i, φ_i and center of gravity are same as obtained from Eq. 6 and Eq. 7. Finally, we get the watermarked 3-D mesh.

C. Watermark Extraction

Watermark extraction is just reverse process of watermark embedding. Vertices of watermarked mesh are selected and converted from Cartesian to spherical coordinates in the same way as in the embedding process. Radial distance is divided into bins and normalized using Eq. 8 and Eq.

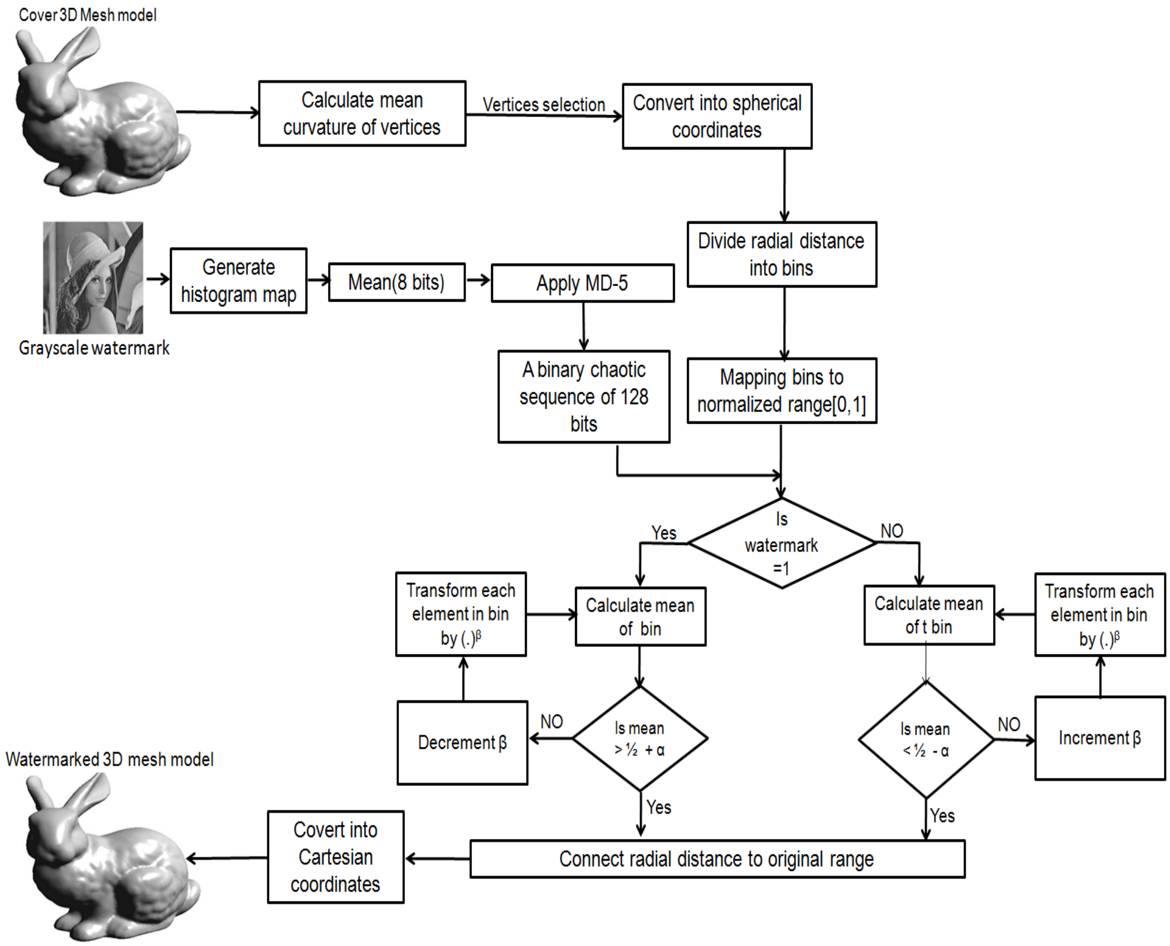

Fig. 4. Block Diagram of Embedding Process.

Algorithm 1: Iterative algorithm to determine the value of parameter β and embed watermark bits in bins.

Require: Normalized bins
Ensure: Watermarked bins STATE Initialize β=1 and $\delta\beta$=0.001

1: Transform each normalized radial distance in the bin using Eq. 10.
2: Calculate mean of transformed elements of bin using following equation:
3: $\mu_n = \frac{1}{M_n} \sum_{j=0}^{M_n - 1} \rho'_{n,j}$
4: **if** W=1 **then**
5:     **if** mean¡(1/2)+α **then**
6:         $\beta = \beta - \delta\beta$
7:         Goto line number 2.
8:     **end if**
9: **else if** W=0 **then**
10:     **if** mean¡(1/2)-α **then**
11:         $\beta = \beta + \delta\beta$
12:         Goto line number 2.
13:     **end if**
14: **end if**
15: Watermarked and transformed bin is obtained

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9. Then mean of each bin is compared with the reference value to extract the watermark. Original mesh is not required for extraction therefore extraction process is blind. More than one, independent watermark sequences are extracted from the bins. These watermark sequences are compared and according to the majority, the final watermark sequence is determined. It acts as error correction mechanism. For example, if i^{th} bit of extracted watermarks has majority of 1 then the final watermark bit is 1; otherwise 0. Finally, the extracted watermark W' is obtained. Fig. 5 shows the block diagram of extraction process. Steps for watermark extraction are explained below.

Steps of watermark extraction process

Step 1: Vertices are selected and converted into spherical coordinates as done in step 1 and 2 of watermark embedding process.

Step 2: Bins of radial distance are formed and normalized in the fashion similar to step 3 and 4 of embedding process.

Step 3: Mean is calculated for individual bin and compared with the reference value to extract watermark bits. One bit is extracted from each bin using following relation:

$$w_n^{'} = \begin{cases} 1 & if \quad \mu_n^{'} > 1/2 \\ 0 & if \quad \mu_n^{'} < 1/2 \end{cases} \tag{16}$$

Where $w_n^{'}$ is the extracted watermark bit from n^{th}, $\mu_n^{'}$ is the mean of each bin.

Step 4: More than one watermark sequences are extracted. Watermark sequences are compared and the final watermark is decided on the basis of majority. Thus, we get 128-bit extracted watermark sequence ($W^{'}$) .

IV. Experimental Result and Discussion

This section presents experimental results to demonstrate the performance of proposed 3-D mesh watermarking scheme. Experiments were conducted to examine the robustness and imperceptibility of the proposed scheme using MATLAB on a PC with Intel core2 Duo, 3.00 GHz, 2GB RAM. Five different 3-D models i.e. Bunny, Armadillo, Dragon, Hand and Venus as shown in Fig. 6 were taken as test data set. These models represent variation of shapes and surfaces. Characteristics of 3-D test models are provided in Table II. Fig. 7 shows the watermarked mesh. For experimental evaluation, 128-bit binary watermark sequence, generated by the watermark generation process discussed in section 3.1 is used. The embedding capacity will vary for different 3-D mesh. This is due to lack of well-defined order and connectivity of vertices.

TABLE II. Characteristics of 3-D Mesh Models

Object Model	Bunny	Armadillo	Dragon	Hand	Venus
No. of vertices	34835	30995	35000	36619	100759
No. of faces	69666	61986	70216	72958	201514

A. Imperceptibility (Visual Masking)

Imperceptibility is one of the most important requirements for 3-D watermarking. Watermarking should cause minimum surface distortion so that it is not visible to human visual system (HVS). Subjective and objective analysis of visual quality of watermarked models is carried out. Subjective analysis is as important as objective analysis because sometimes the objective parameter may demonstrate good results but visual quality of 3-D object is not good. Mean opinion score (MOS) suggested by Corsini et al. [28] is used as metric for subjective analysis. Watermarked models are manually compared with original model from different angles. Observer assigns score between 0 and 10 to the watermarked mesh where 0 and 10 represents lowest and highest visual quality respectively. A normalized MOS is computed for each model by averaging the scores given by observers using following equation:

$$MOS_x = \frac{1}{N}\sum_{y=1}^{N} S_{xy} \tag{17}$$

Where MOS_x is the mean opinion score of x^{th} model, N is the number of observer and S_{xy} is the score for x^{th} model by y^{th} observer.

Maximum root mean square error (MRMS) and Hausdorff distance(HD) are used as metric for objective analysis. MRMS

TABLE III. MRMS, MOS and Hausdorff Distance for Watermarked Models

Object models	Bunny	Armadillo	Dragon	Hand	Venus
MRMS ($\times 10^3$)	0.243	0.255	0.283	0.271	0.240
MOS	9.93	9.88	9.49	9.91	9.84
Hausdorff Distance	0.001	0.001	0.001	0.001	0.001

measures surface-to-surface distance between the two meshes. Smaller MRMS value indicates better visual quality. MRMS is calculated by following equation:

$$MRMS = max(err_{RMS}(M, M^{'}), err_{RMS}(M^{'}, M)) \tag{18}$$

where err_{RMS} is the root mean square error. err_{RMS} from one mesh M to another mesh $M^{'}$ is given by:

$$err_{RMS}(M, M^{'}) = (1/|M|)^{1/2} \iint_{p \epsilon M} d(p, M^{'})^2 dM \tag{19}$$

where p is a point on the surface of mesh M. $|M|$ is the area of M and d(p,M') is the point-to-surface distance between p and M.

HD is the maximum distance of a set to the nearest point in the other set of object. HD from set A to set B is a max-min function, defined as

$$HD(O, O^w) = max\left\{min\left\{d\left(a, b\right)\right\}\right\} \tag{20}$$

where, a and b are points of original set O and watermark object O^w respectively, and d (a, b) is any metric between these points.

To study the imperceptibility and distortion in watermarked model, both subjective and objective evaluation is done in terms of MRMS,MOS and HD and the results are tabulated in Table III. Subjectively analysis, of original and watermarked models reveals that there is no significant visual distortion is induced. Table III shows that MOS is close to 10 in all models which indicate that no significant perceivable distortion is caused by the proposed scheme. It can be observed from Table III that MRMS and HD values are also very low. Hence, the proposed scheme satisfies both the perceptual and the geometric quality in the 3-D Mesh watermarking.

B. Robustness Evaluation

Robustness is another important requirements of 3-D mesh watermarking scheme. Robustness of proposed scheme is evaluated under different common attacks like, smoothing attack, cropping attack, noise addition, quantization, similarity transformation, simplification attack and scaling on Z axis. Simulation of noise addition and scaling attack is done in MATLAB whereas smoothing, simplification and cropping attacks is simulated by Meshlab open source [28]. Also, the robustness of the proposed scheme is evaluated under attacks of Meshbenchmark tool. Correlation coefficient and BER is used to measure the robustness. It measures the similarity between embedded and extracted watermark and can be express as following equation:

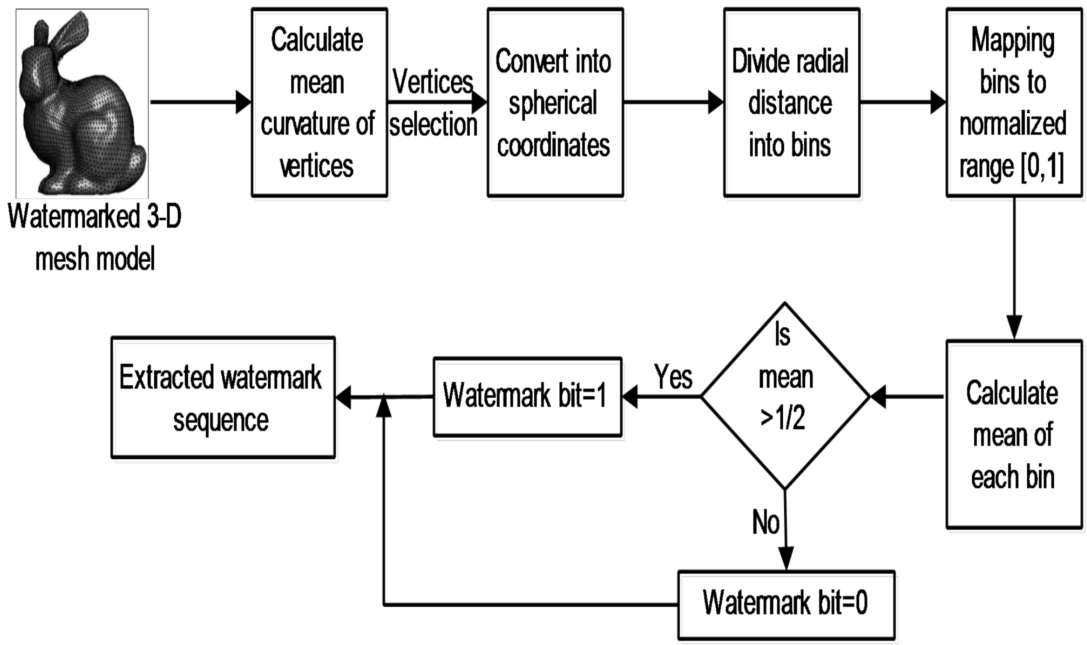

Fig. 5. Block Diagram of Extraction Process.

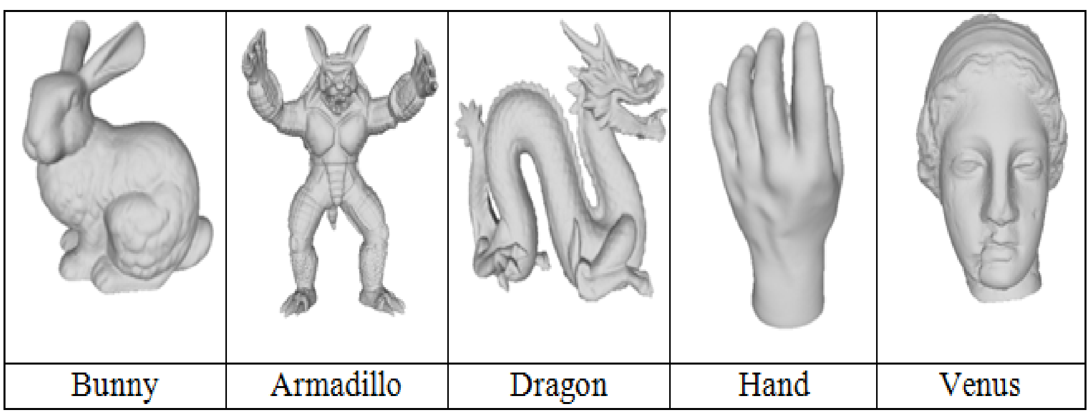

Fig. 6. Original 3-D Mesh Models.

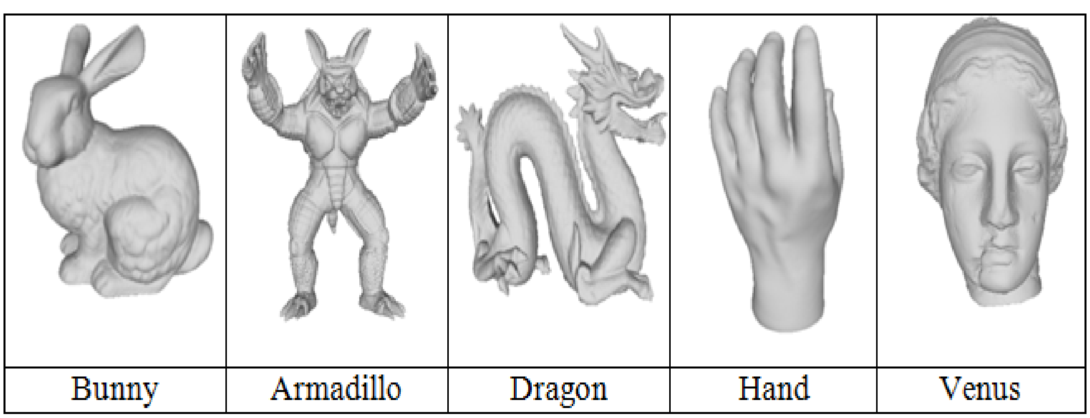

Fig. 7. Watermarked 3-D Mesh Models.

$$Corr(W,W^{'}) = \sum_{i=0}^{L-1}(w_i^{'} - \bar{w'})(w_i - \bar{w}) \\ /(\sum_{i=0}^{L-1}(w_i^{'} - \bar{w'})^2 \sum_{i=0}^{L-1}(w_i - \bar{w})^2)^{1/2} \tag{21}$$

where W and $W^{'}$ are embedded and extracted watermark respectively. $\bar{w}$ and $\bar{w'}$ are the mean of embedded and extracted watermark, w_i and $w_i^{'}$ are the i^{th} watermark bit of embedded and extracted watermark, respectively. Correlation ranges in [-1,1] and the ideal value is 1.

When the watermark is extracted from watermarked model without any attack, the corr value is 0.9992 quite close to the ideal value. Watermark embedding process effects the correct bin division in the watermark extraction process therefore ideal value of corr could not be achieved.

1) Robustness Against Smoothing Attack: Smoothing is commonly used to eliminate the noise introduced during the mesh generation process. There are many smoothing algorithms out of which Laplacian smoothing algorithm proposed in [29] is commonly used. Therefore, in existing literature majority of the 3-D watermarking schemes test robustness of their scheme under Laplacian smoothing attack. It is an iterative process where vertex position is calculated by averaging its neighbours and the weight is determined according to its local connectivity. The results of Laplacian smoothing with different number of iteration ranging from 10-50 and keeping deformation factor λ=0.03 is presented in Table VI. From Table VI, it can be observed that the corr value for all models is appreciable upto 30 iterations. Also, the extracted watermark is distinguishable for less than 50 iterations as the normalized correlation is above the threshold value. Hence, the proposed scheme has fair robustness under smoothing attack.

2) Robustness Against Cropping: Cropping attack deletes vertices from one or more parts of a 3-D mesh model. It destroys the watermark information from the cropped region but watermark can be validated from the remaining portion. Cropping attack does not destroy all watermarked vertices because watermark bits are scattered uniformly. In the proposed scheme watermark is repetitively embedded to resist cropping attack. From the Table IV it can be observed that corr value for 10%, 20% and 25% cropping are more than 0.92, 0.83 and 0.75 indicating that extracted watermark is distinguishable. Thus, the proposed scheme is robust against cropping attack, because for all models corr value is more than the threshold.

TABLE IV. CORR VALUES FOR 3-D MODELS UNDER CROPPING ATTACK

Cropping %	Bunny	Armadillo	Dragon	Hand	Venus
10	0.9235	0. 9556	0.9375	0.9607	0.9451
20	0.8371	0.8593	0.8299	0.8788	0.8488
25	0.7598	0.7827	0.7621	0.7494	0.7399

3) Robustness Against Simplification Attack: Mesh simplification is commonly used operation particularly for compression. A highly detailed mesh can be simplified or conversely increase the complexity of simplified mesh. Table V shows Corr values for varying simplification ratio. The proposed scheme shows satisfactory resistance towards simplification attack.

TABLE V. CORR VALUES FOR 3-D MODELS UNDER SIMPLIFICATION ATTACK

Simplification vertex reduction ratio (%)	Bunny	Armadillo	Dragon	Hand	Venus
70	0.9046	0.8571	0.8735	0.8579	0.8699
90	0.8136	0.7889	0.8025	0.7792	0.7964

TABLE VI. CORR VALUES FOR 3-D MODELS UNDER LAPLACIAN SMOOTHING ATTACK(λ=0.03)

Iterations	Bunny	Armadillo	Dragon	Hand	Venus
10	0.9386	0.9025	0.9144	0.9247	0.9197
30	0.8692	0.8703	0.8463	0.8836	0.8961
50	0.6173	0.6899	0.5894	0.6391	0.5939

4) Robustness Against Random Additive Noise: Noise attack is very common during data transmission and mesh object operation like read/write. Pseudo random noise (amplitude ϵ $0.05\%, 0.25\%, 0.5\%$) is added on vertex to distort the watermark. Experimental results of random additive noise attacks in Table VII shows that proposed scheme shows good robustness even at high noise ratio of 0.5%.

TABLE VII. CORR VALUES FOR 3-D MODELS UNDER ADDITIVE NOISE ATTACK

Noise %	Bunny	Armadillo	Dragon	Hand	Venus
0.1	0.9883	0.9497	0.9578	0.9479	0.9397
0.3	0.9146	0.8692	0.8749	0.8491	0.8739
0.5	0.8139	0.7616	0.7509	0.7787	0.7989

5) Robustness Against Quantization Attack : Quantization is lossy compression method. We have evaluated robustness of our scheme against different quantization rate. Vertex coordinate is represented with 7, 8 and 9 bits. Table VIII shows the corr values against different quantization attack. Proposed method is robust for 9-bit and 8-bit quantization attack.

TABLE VIII. CORR VALUES FOR 3-D MODELS UNDER ADDITIVE QUANTIZATION ATTACK

Quantization %	Bunny	Armadillo	Dragon	Hand	Venus
9 bits	0.9983	0.9448	0.9753	0.9488	0.9961
8 bits	0.9461	0.9121	0.8942	0.8813	0.8498
7 bits	0.6191	0.7114	0.5529	0.6771	0.7389

6) Robustness Against Similarity Transform: It is desireable for any 3-D watermarking scheme to be robust against similarity transform as it includes rotation, translation, and uniform scaling attack. Table IX presents corr values under similarity transformation. It can be observed from Table IX that the proposed watermarking scheme is robust against this attack for all 3-D model used for evaluation.

7) Robustness Against Scaling Attack on Z-axis : Uniform scaling attack on Z-axis having scaling factor 1.25 is applied on 3-D models. Results are tabulated in following Table X. Proposed scheme is fairly robust against scaling attack.

TABLE IX. CORR VALUES FOR 3-D MODELS UNDER SIMILARITY TRANSFORMATION

Similarity Transformation	Bunny	Armadillo	Dragon	Hand	Venus
Transformaton1	0.9826	0.9762	0.9635	0.9833	0.9587
Transformaton2	0.9399	0.9527	0.9192	0.9384	0.9086
Transformtion3	0.9188	0.9129	0.8973	0.9118	0.8893

TABLE X. CORR VALUES FOR 3-D MODELS UNDER SCALING ATTACK

Attacks	Bunny	Armadillo	Dragon	Hand	Venus
Scaling on Z-axis (1.25)	0.9921	0.9858	0.9824	0.9907	0.9843

8) Robustness Evaluation using MeshBenchmark Tool: Robustness of the proposed scheme has been evaluated using benchmark tool Meshbenchmark [30] available at http://liris.cnrs.fr/meshbenchmark/. Table XI shows BER values of extracted watermark under various attacks defined by perceptual and geometric quality oriented protocol of Meshbenchmark. From Table XI we observe that the proposed method is more suitable for the applications where the watermarked object of high visual quality is needed.

C. Time Complexity

In this subsection we analyze the asymptotic time complexity of the proposed embedding scheme. While calculating the computational cost we consider the cost of major algorithmic steps for watermark embedding and the most expensive operations only. Computationally expensive operations are as follows:

- Vertex selection: As specified earlier vertices with mean curvature less than zero are selected for embedding. Therefore mean curvature for each vertex is calculated using Eq. 4. Computational cost incurred in 1-ring neighborhood construction by traversing each edge is $O(3V)$ [31]. Therefore computational cost is $O(3V)$.
- Conversion of Cartesian coordinate to spherical coordinate: Each selected vertex is converted from Cartesian to spherical coordinate. Computational cost of conversion is $O(V)$.
- Determination of β and watermark embedding: Value of β is determined by an iterative algorithm. The computational cost is $O(nV)$ where n is the number of iterations.

TABLE XI. BER VALUES UNDER VARIOUS MESHBENCHMARK ATTACKS

Attacks	BER (Perceptual)	BER (Geometric)
Similarity transformation	0.01	0.01
Noise A = 0.10%	0.01	0.04
Noise A = 0.30%	0.08	0.12
Noise A = 0.50%	0.19	0.25
Smoothing N_{itr} = 10	0.13	0.22
Smoothing N_{itr} = 30	0.29	0.37
Smoothing N_{itr} = 50	0.39	0.42
Quantization R = 9	0.09	0.16
Quantization R = 8	0.18	0.21
Quantization R = 7	0.42	0.51
Simplification E_{sim} = 10%	0.01	0.01
Simplification E_{sim} = 30%	0.02	0.03
Simplification E_{sim} = 50%	0.06	0.17
Cropping V_{cr} = 10%	0.51	0.53
Cropping V_{cr} = 30%	0.55	0.56
Subdivision Midpoint	0.01	0.03

Based on the above analysis, we conclude that the proposed watermarking scheme has linear time complexity as:

$$O(3V) + O(V) + O(nV) = O(nV) \tag{22}$$

TABLE XII. AVERAGE NUMBER OF ITERATIONS AND COMPUTATION TIME FOR DETERMINING β PER BIN

Model	Avg. number of iterations	Avg. computation time(ms)
Bunny	154	13.09
Armadillo	358	235.16
Dragon	205	121.83
Hand	139	81.48
Venus	742	533.64

The average number of iteration and computation time required for determining β for each bin is presented in Table XII. The total time required for watermark embedding ranges from 0.6s to 200s subjected to mesh size.

D. Comparative Analysis

To further validate the performance of the proposed scheme, a comparative study is done with existing 3-D mesh watermarking schemes in terms of imperceptibility, robustness and security. Comparison has been done with spatial domain schemes proposed by Zhan et al. [10], Li et al. [13], and transform domain scheme proposed by Hamidi et al. [17]. In the scheme proposed by Zhan et al. [10], watermark bits are interleaved in bins formed on the basis of vertex curvature. Similarly, Li et al. [13] suggested to form bins of eigen values (distance between vertice to the model center) based on improved vertex grouping. It uses piecewise mapping function to insert watermark bits in the bins. Both the watermarking schemes are in spatial domain and blind. They show improved imperceptibility and robustness than [11], but none of the them have taken security requirement of watermarking in account. Hamid et al. [17] have proposed to a blind watermarking scheme in transform domain, where watermark is embedded in quantified wavelet coefficients using QIM based on 3-D mesh saliency. Though the scheme achieves good imperceptibility and robustness but, it is not able to resist cropping attack. They have used key, but its effectiveness in providing security is debatable. Schemes in comparison, assert to have better performance than the state-of-the-art schemes in exsisting litreature.

Imperceptibility of the proposed scheme is compared with the other counterparts [10], [13], [17] in terms of MRMS value. Fig. 8 shows the MRMS value for three watermarked 3-D mesh (without attack) i.e. Bunny, Dragon and Venus. MRMS value of the proposed scheme is lower than [10], [17] and quite equal to [13]. Hence, it can be inferenced that the proposed scheme outperforms [10], [17] and is at par with [13] in terms of imperceptibility. Higher imperceptibility of the proposed scheme can be attributed to the embedding of watermark bits in deeper vertices.

Further, comparison of performance under different attacks is studied in terms of Corr and MRMS value. Table XIII shows comparison of robustness and imperceptibility of the proposed scheme with Zhan et al. scheme [10]. It can be observed from

TABLE XIII. Comparison of Corr and MRMS Values of Proposed Scheme with Zhan et al. Scheme [10]

Models	Attacks	Parameters	Proposed Scheme		Zhan et al. [10]	
			Corr	MRMS	Corr	MRMS
Bunny	Smoothing	$N_{iter} = 10$	**0.9386**	**0.18**	0.92	0.26
		$N_{iter} = 30$	**0.8692**	**0.53**	0.85	0.70
		$N_{iter} = 50$	**0.6173**	**0.64**	0.44	0.97
	Quantization	9-bit	**0.9968**	**0.49**	1.00	0.61
		8-bit	**0.9562**	**0.88**	0.91	1.00
		7-bit	**0.7311**	**1.12**	0.58	1.84
	Simplification	70%	0.9046	**0.23**	1.00	0.40
		90%	0.7936	**0.41**	0.83	0.54
	Noise	0.1%	0.9883	**0.27**	1.00	0.32
		0.3%	0.8463	**0.36**	0.91	0.40
		0.5%	**0.8139**	**0.59**	0.80	0.98
	Cropping	25%	**0.7598**	**0.81**	0.73	1.02
Dragon	Smoothing	$N_{iter} = 10$	**0.9144**	**0.28**	0.91	0.33
		$N_{iter} = 30$	**0.8463**	**0.79**	0.66	0.80
		$N_{iter} = 50$	**0.5894**	**0.91**	0.44	1.12
	Quantization	9-bit	**0.9782**	**0.48**	0.96	0.55
		8-bit	**0.7911**	**0.86**	0.77	1.13
		7-bit	**0.5681**	**0.95**	0.41	1.89
	Simplifcation	70%	0.8735	**0.31**	0.95	0.33
		90%	0.8025	**0.22**	0.66	0.97
	Noise	0.1%	0.9578	0.33	1.00	0.32
		0.3%	0.8692	**0.59**	0.91	0.62
		0.5%	0.7609	**0.93**	0.77	1.01
	Cropping	25%	**0.7827**	**0.95**	0.77	1.01
Venus	Smoothing	$N_{iter} = 10$	0.9197	0.28	1.00	0.12
		$N_{iter} = 30$	0.8961	**0.31**	0.97	0.24
		$N_{iter} = 50$	0.5939	**0.49**	0.93	0.59
	Quantization	9-bit	0.9963	**0.52**	1.00	0.64
		8-bt	**0.9485**	**0.93**	0.83	1.12
		7-bit	**0.8428**	**1.02**	0.73	1.75
	Simplification	70%	0.8699	**0.24**	1.00	0.30
		90%	0.7964	0.33	0.96	0.32
	Noise	0.1%	0.9397	0.27	0.95	0.24
		0.3%	0.8739	**0.48**	0.95	0.58
		0.5%	**0.7989**	1.01	0.79	0.99
	Cropping	25%	**0.7494**	**0.89**	0.72	0.96

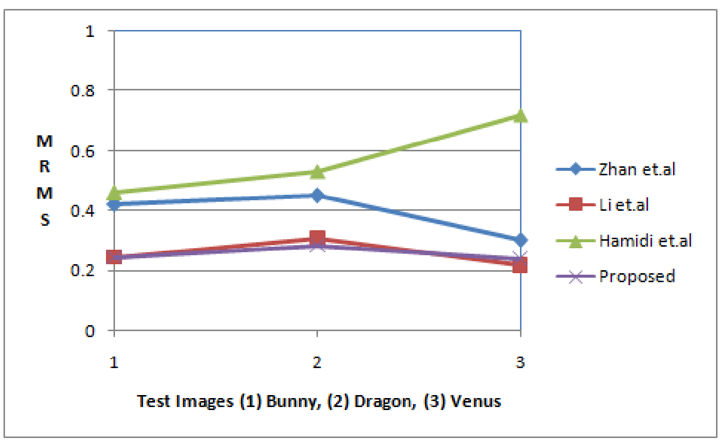

Fig. 8. MRMS Value for Watermarked Bunny, Dragon and Venus for Schemes Proposed in [10], [13], [17].

Table XIII that the proposed scheme has higher robustness and imperceptibility under smoothing, quantization and cropping attack for majority of models in comparison. In simplification attack, correlation value of the proposed scheme is lesser than [10] but higher than the threshold. Under these attacks, MRMS values are comparitively higher for the proposed scheme indicating higher imperceptibility. And, the proposed scheme has vying performance against simplification, noise and scaling attack. Therefore, it can be said that the proposed scheme outperforms in most of the common attacks than Zhan et al. scheme [10]. Similarly, performance comparision of the proposed scheme has been done with Li et al. scheme [13] in Table XIV. It can be observed from Table XIV that the proposed scheme outperforms [13] in terms of imperceptibility under all attacks. The proposed scheme performs better under smoothing and quantization attacks. Though, the robustness of the Li et al. scheme [13] is higher under noise attack than the proposed scheme but lags behind in imperceptibility. Thus, we can deduce that the proposed scheme outdo [13]. Performance of the proposed scheme is also compared with Hamidi et al. scheme [17] under different attacks for Bunny model and the results have been tabulated in Table XV. It can be observed that the proposed scheme is more robust than Hamidi et al. scheme [17] under common attacks except noise attack.

TABLE XIV. Comparison of Corr and MRMS Values of Proposed Scheme with Li et al. Scheme [13] under Different Attacks

Models	Attacks	Parameters	Proposed Scheme		Song Li et al. [13]	
			Corr	MRMS	Corr	MRMS
Bunny	Smoothing	$N_{iter} = 10$	0.9386	**0.18**	1.00	0.342
		$N_{iter} = 30$	**0.8692**	**0.53**	0.77	0.705
		$N_{iter} = 50$	**0.6173**	**0.64**	0.38	1.046
	Quantization	9-bit	**0.9968**	**0.49**	0.97	0.528
		8-bit	**0.9562**	**0.88**	0.58	1.076
		7-bit	**0.7311**	**1.12**	0.17	2.085
	Noise	0.1 %	0.9883	**0.27**	1.00	0.327
		0.3%	0.8463	**0.36**	0.90	0.712
		0.5%	**0.8139**	**0.59**	0.68	1.141
Dragon	Smoothing	$N_{iter} = 10$	0.9144	**0.28**	1.00	0.412
		$N_{iter} = 30$	**0.8463**	**0.79**	0.80	0.856
		$N_{iter} = 50$	**0.5894**	**0.91**	0.55	1.301
	Quantization	9-bit	**0.9782**	**0.48**	0.97	0.643
		8-bit	**0.7911**	**0.86**	0.52	1.181
		7-bit	**0.5681**	**0.95**	0.25	2.319
	Noise	0.1%	0.9578	**0.33**	1.00	0.391
		0.3%	0.8692	**0.59**	1.00	0.795
		0.5%	0.7609	**0.93**	0.97	1.255
Venus	Smoothing	$N_{iter} = 10$	0.9197	0.28	1.00	0.238
		$N_{iter} = 30$	0.8961	**0.31**	0.94	0.379
		$N_{iter} = 50$	0.5939	**0.49**	0.72	0.535
	Quantization	9-bit	0.9963	**0.52**	0.88	0.697
		8-bt	**0.9485**	**0.93**	0.58	1.340
		7-bit	**0.8428**	**1.02**	-0.12	2.704
	Noise	0.1%	0.9397	0.27	1.00	0.391
		0.3%	0.8739	**0.48**	0.72	1.006
		0.5%	**0.7989**	1.01	0.25	1.654

TABLE XV. Comparison of Corr Values of Proposed Scheme and Hamidi et al. scheme [17] for Bunny

Attacks	Parameters	Proposed	Hamidi et al. [17]
		Corr	Corr
Smoothing	$N_{iter} = 10$	**0.9386**	0.92
	$N_{iter} = 30$	**0.8692**	0.88
	$N_{iter} = 50$	0.6173	0.71
Quantization	9-bit	**0.9968**	0.99
	8-bit	**0.9562**	0.95
	7-bit	0.7311	0.89
Noise	0.1%	0.9883	0.99
	0.3%	0.8463	0.90
	0.5%	0.8139	0.84
Simplification	70%	**0.9046**	0.71
	90%	**0.7936**	0.46
Cropping	25%	**0.7598**	0.48

An overall comparison of robustness for the proposed scheme and counterpart schemes [10], [13], [17] under smoothing, quantization and noise is presented in Fig. 9, Fig. 10 and Fig. 11 respectively. Fig. 9 shows that under smoothing attack, the proposed scheme has higher robustness than [10], [13] but lags behind [17] when number of iterations are increases more than 40. Under quantzation attack the proposed scheme has

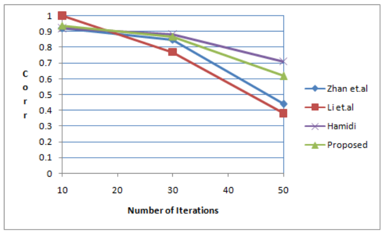

Fig. 9. Comparison of Corr Values of Proposed Scheme with [10], [13], [17] under Smoothing Attack .

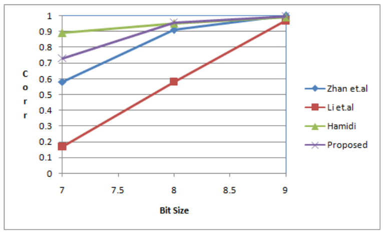

Fig. 10. Comparison of Corr Values of Proposed Scheme with [10], [13], [17] under Quantization Attak .

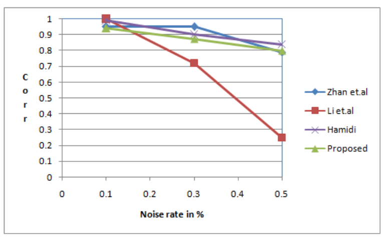

Fig. 11. Comparison of Corr Values of Proposed Scheme with [10], [13], [17] under Noise Attack.

better performance than [10], [13] and is at par with [17] as shown in Fig. 10. The proposed scheme is more robust than [13] under noise attack and passable in comparison to schemes in [10], [17]. Similarly, an overall comparison of imperceptibility is presented in Fig. 12, Fig. 13 and Fig. 14. From these figures, it can be observed that the proposed scheme has appreciably lower MRMS values than [10], [13], [17] under smoothing, quantization and noise. This indicates that the proposed scheme has higher imperceptibility. Hence, from the comparative study we can conclude that the proposed scheme shows overall improved performance than [10], [13], [17] in terms of imperceptibility, robustness and has higher security.

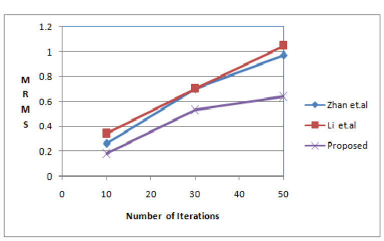

Fig. 12. Comparison of MRMS Values of Proposed Scheme with [10], [13], [17] under Smoothing Attack .

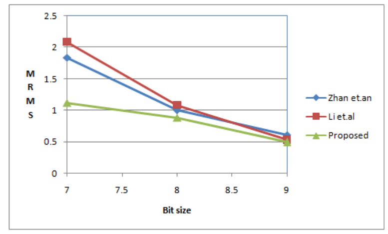

Fig. 13. Comparison of MRMS Values of Proposed Scheme with [10], [13], [17] under Quantization Attack.

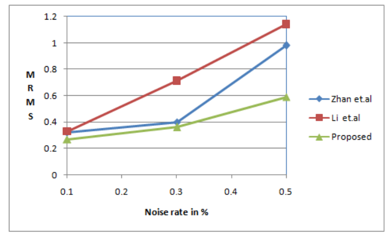

Fig. 14. Comparison of MRMS Values of Proposed Scheme with [10], [13], [17] under Noise Attack.

V. Conclusion

In this paper, a blind, robust, and secure 3-D mesh watermarking scheme is proposed that embeds watermark bits by modulating the radial distance distribution of deeper vertices using histogram mapping function. A unique watermark sequence is generated using MD5 hash function according to the grayscale watermark/logo to ensure higher security. Experimental evaluation of watermarked 3-D models reveals that no significant distortion is induced by watermarking process hence, the visual quality is good. Also, that the proposed scheme is robust against various common attacks like smoothing, additive noise, quantization, similarity transformation, cropping and simplifi- cation. Comparative analysis reflects that the proposed scheme outperforms the existing schemes and may find potential solution to the copyright pro- tection applications. Since watermark bits are embedded in deeper vertices of 3-D mesh, this scheme may not be effective for models with only positive mean curvature or flat models. This can be seen as a scope for future work. In future we wish to improve robustness of the proposed scheme using hybrid transforms.

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Optimized Design of a Converter Decimal to BCD Encoder and a Reversible 4-bit Controlled Up/Down Synchronous Counter

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***Abstract*—The field of quantum computing, reversible logic, and nanotechnology have earned much attention from researchers in recent years due to their low power dissipation. Quantum computing has been a guiding light for nanotechnology, optical computing of information, low power CMOS design, computer science. Moreover, the dissipation of energy in the field combinatorial logic circuits becomes one of the most important aspects to be avoided. This problem is remedied by a reversible logic favoring the reproduction of inputs to outputs, which is due to the absence of unused bits. Every bit of information not used generates a loss of information causing a loss of energy under the form of heat, the reversible logic leads to zero heat dissipation. Among the components affected by reversible logic are binary reversible counter and converter from decimal to BCD encoder(D2BE) which are considered essential elements. This article will propose an optimized reversible design of a converter from decimal to BCD encoder (D2BE) and an optimized design of reversible Binary counter with up/ down. Our designs show an improvement compared to previous works by replacing some reversible gates with others while keeping the same functionality and improving performance criteria in terms of the number of gates, garbage outputs, constant inputs, quantum cost, delay, and Hardware complexity.**

Keywords*—Decimal to BCD Encoder (D2BE); Reversible Binary Counter; Number of Gates (CG); Number of Garbage Output (NGO); Number of Constant Inputs (NCI); Quantum Cost (QC); Hardware Complexity (HC)

I. Introduction

In the irreversible logic, the design of circuits becomes more and more difficult in terms of material design, this is due to the dissipation of energy in the form of heat which is generated at the end of the lost or unused bits. In irreversible logical calculation, each unused bit generates a loss of energy which is expressed by the formula KTln2 or K: constant of BOLTZMAN and T: absolute temperature related to calculation, this formula was established by Landauer in 1960 [1]. In digital circuits, energy loss is a function of garbage outputs (unused bits). Bennett has proven that this loss of energy can be avoided by a reversible logic using reversible gates [2]. Toffoli [3] shown in 1980 that to avoid a zero internal power circuit, it can be designed using reversible logic gates which, inside each of them, have a certain bijectivity [4-6] between inputs and outputs. Each reversible gate must have a tie between the number of inputs and that of outputs [4-6] and each input vector can be uniquely deduced from the output vector [4-6]. Performance criteria to be improved and concerned by this study are: Number of gates (CG), Number of garbage outputs (NGO) The number of constant inputs (NCI) and Quantum cost (QC). Fredkin and Toffoli have shown that the more NCI and NGO are minimized, the more efficient the circuit design is improved [7]. It was shown in [8-10] that the decrease in energy dissipation in the form of heat is proportional to the minimization of the NGO which shows the great importance of these criteria.

Our work will be divided into two parts the first concerns the design of a converter from decimal to BCD encoder based on a recent study design6 [14]: to modify it and improve the performance criteria compared to the latter and even to the five other studies design5 [14], design4 [13], design3 [12], design2 [12] and design1 [11]. The second concerns the design of a reversible binary counter based on a recent study design3 [17]by modifying it while keeping its same functionality and increasing the performance criteria compared to the latter and even to the two other studies design2 [16] and design1 [15].

The rest of this article is organized as follows: the second section presents the reversible gates concerned by this article by showing their performance criteria, namely the quantum cost that is deducted from the associated quantum implementation, and the hardware complexity. The third section presents a literature review of the recent designs proposed related to each study the design of the converter from decimal to BCD encoder and the reversible binary counter while showing the performance criteria of each, for the first study we have six proposals designs and for the second one we have three.

The fourth section shows our proposed designs of the D2BE circuit and reversible binary counter. The fifth section will show the result and discussion of our work by revealing our proposed designs and calculate our performance criteria while showing the percentages of improvement obtained.

Finally, a conclusion and perspectives in the last section.

II. The Reversible Gates Concerned by the Study and their Performance Criteria

In this section we will define the six performance criteria concerned by this article which are:

A. Performance Criteria

1) Number of Gates (CG): The number of gates required to make a circuit [18].

2) Number of garbage outputs (NGO): The unused or unwanted logic outputs of the reversible gate maintain in the output lines to make the circuit reversible [22].

3) Number of Constant Inputs (NCI): The number of inputs must remain constant at 0 or 1 to integrate the given logic function [6].

4) Quantum Cost (QC): The QC is calculated by counting the number of one input–output and two input–output reversible gates used in realizing a circuit [19,20]. The QC of one input–output and two input–output reversible gates is realized to be 1.

5) Hardware Complexity (HC): The number of fundamental operations (Ex-OR, AND, NO, etc.) required to make the circuit. Actually, a constant complexity is supposed for each fundamental operation of the circuit, such as α for Ex-OR, β for AND, δ for NOT, etc. Eventually, the entire number of operations is calculated in terms of α, β, and δ [23].

In this part, we will present the reversible gates that we will use in this article by showing their performance criteria, specially the quantum cost that we deduce directly from the quantum implementation, and its hardware complexity.

B. Feyman Gate FG

A reversible gate 2 * 2 have as inputs A and B and as outputs P = A and Q = A $\bigoplus$ B. The quantum cost of the gate FG is worth QC = 1, its Hardware complexity is worth HC = 1α [18].

C. TS-3 Gate

A reversible gate 3 * 3 have for inputs A, B and C and as outputs P = A, Q = B and R = A $\bigoplus$ B . The quantum cost of the TS-3 gate is equal to QC = 2, its Hardware complexity is worth HC = 2 α [24].

D. Fredkin Gate FRG

A reversible gate 3 * 3 have as inputs A, B and C and as outputs P = A, Q = A'B $\bigoplus$ AC and R = A'C $\bigoplus$ AB. The quantum cost of the FRG gate is equal to QC = 2, its Hardware complexity is equal to HC = 2 α + 4 β + 1 δ [18].

E. Peres Gate PG

A reversible gate 3 * 3 have as inputs A, B and C and as outputs P = A, Q = A $\bigoplus$ and R = AB $\bigoplus$ C. The quantum cost of the gate PG is equal to QC = 4, its Hardware complexity is worth HC = 2 α + 1 β [25].

F. HNFG Gate

A reversible gate 4 * 4 have for inputs A, B, C and D as outputs P = A, Q = A $\bigoplus$ C, R = B and S = B $\bigoplus$ D. The quantum cost of the HNFG gate is equal to QC = 4, its Hardware complexity is worth HC = 2 α [18].

G. HNG Gate

A reversible gate 4 * 4 have as inputs A, B, C and D as outputs P = A, Q = B, R = A $\bigoplus$ B $\bigoplus$ C and S = (A $\bigoplus$ B) C $\bigoplus$ AB $\bigoplus$ D. The quantum cost of the HNG gate is equal to QC = 6, its Hardware complexity is worth HC = 4 α + 2 β[18].

H. RSJ Gate

A reversible gate 4 * 4 have as inputs A, B, C and D as outputs P = A, Q = B, R = AB $\bigoplus$ C, S = AB $\bigoplus$ D.The quantum cost of the RSJ gate is equal to QC = 12 and its Hardware complexity is equal to HC = 2 α + 1 β [26].

I. TFG Gate

A reversible gate 4 * 4 have as inputs A, B, C and D as outputs P = A, Q = A $\bigoplus$ B, R = AB $\bigoplus$ C, S = AB $\bigoplus$ C $bigoplus$ D. The quantum cost of the TFG gate is equal to QC = 5 and its Hardware complexity is equal to HC = 3 α + 1 β [15].

J. TKS Gate

A reversible gate 4 * 4 have as inputs A, B, and C as outputs P = AC '+ BC, Q = A $\bigoplus$ B $\bigoplus$ C, R = AC + BC'. The quantum cost and the Hardware complexity of the TKS gate is not mentioned [27].

K. MSH Gate

A reversible gate 4 * 4 have as inputs A, B, C and D as outputs P = A, Q = B $\bigoplus$ C, R = A'C $\bigoplus$ AB and S = A'C $\bigoplus$ AB $\bigoplus$ D. The quantum cost of the MSH gate is equal to QC = 6 and its Hardware complexity is equal to HC = 3 α + 2 β + 1 δ [28].

L. NP Gate

A reversible gate 4 * 4 have as inputs A, B, C and D as outputs P = A, Q = A'B $\bigoplus$ AC ', R = A'C $\bigoplus$ AB and S = A'C $\bigoplus$ AB $\bigoplus$ D. The quantum cost of the gate NP is equal to QC = 5 and its Hardware complexity is equal to HC = 3 α + 4 β + 2 δ [29].

M. BJN Gate

A reversible gate 3 * 3 have as inputs A, B and D as outputs P = A, Q = B, R = (A + B) $\bigoplus$ C. The quantum cost of the gate BJN is equal to QC = 5 and its Hardware complexity is HC = 3 α + 4 β + 2 δ [30].

N. Sayem Gate SG

A reversible gate 4 * 4 have as inputs A, B, C and D as outputs P = A, Q = A'B $\bigoplus$ AC, R = A'B $\bigoplus$ AC $\bigoplus$ D and S = AB $\bigoplus$ A'C $\bigoplus$ D. The quantum cost of the gate SG is equal to QC = 5 and its Hardware complexity is equal to HC = 4 α + 4 β + 1 δ [31].

III. Literature Review

We will present all the recent studies related to our proposed designs, starting by:

A. Design of the Converter from Decimal to BCD Encoder or D2BE

The decimal number system is made up of ten numbers from zero to nine to convert it in BCD Format, using a system called D2BE composed of ten inputs and four outputs. the inputs range from D0 to D9 and the outputs are A, B, C, and D [11] [12] [21] outputs are expressed depending on the inputs as follows:
A = D8 $\bigoplus$D9
B = D4 $\bigoplus$ D5 $\bigoplus$ D6 $\bigoplus$ D7
C = D2 $\bigoplus$ D3 $\bigoplus$ D6 $\bigoplus$ D7
D = D1$\bigoplus$D3 $\bigoplus$ D5 $\bigoplus$ D7 $\bigoplus$ D9
Table I presents the truth table of the converter from decimal to BCD encoder.

TABLE I. D2BE CONVERTER TRUTH TABLE

D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	A	B	C	D
0	0	0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0	0	1
0	0	0	0	0	0	0	1	0	0	0	0	1	0
0	0	0	0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	0	1	0	0	0	0	0	1	0	0
0	0	0	0	1	0	0	0	0	0	0	1	0	1
0	0	0	1	0	0	0	0	0	0	0	1	1	0
0	0	1	0	0	0	0	0	0	0	0	1	1	1
0	1	0	0	0	0	0	0	0	0	1	0	0	0
1	0	0	0	0	0	0	0	0	0	1	0	0	1

The inputs of the converter from decimal to BCD encoder are: D9, D8, D7, D6, D5, D4, D3, D2, D1 and D0 and its outputs are:A,B,C and D.

We present below the related recent studies:

1) Design1: In 2012 JUN-CHAO WANGI [11] designed the converter from decimal to BCD encoder composed of five CNOT gates and fifteen Toffoli Gate gates (Fig. 1). According to the circuit proposed by JUN-CHAO WANGI, we have the performance criteria as follows:

-Number of gates: Its proposed circuit consists of five CNOT gates and 15 Toffoli gates. therefore CG = 20.

-Number of garbage outputs: As it indicated NGO = 25.

-Number of constant inputs: This criteria is not mentioned.

-Quantum cost: Its circuit is composed of five CNOT reversible gates having QC = 5 (QC = 1 for each) and fifteen TG reversible gates having QC = 75 (QC = 5 for each) therefore QC = 80.

-Hardware complexity: The circuit contains five CNOT reversible gates and fifteen TG reversible gates so HC =5α + 15(1α +1β) =20α+15β.

2) Design2 and Design3: In 2014 VANDANA SHUKLA [12] designed 2 designs of the decimal to BCD converter encoder which are as follows:

*Design2: This design is the circuit of the converter from decimal to BCD encoder design2 as shown in Fig. 2. According to this proposed circuit we have the performance criteria as follows:
-Number of gates: Its proposed circuit consists of 12 FG gates including four gates reversible TKS therefore CG = 16.

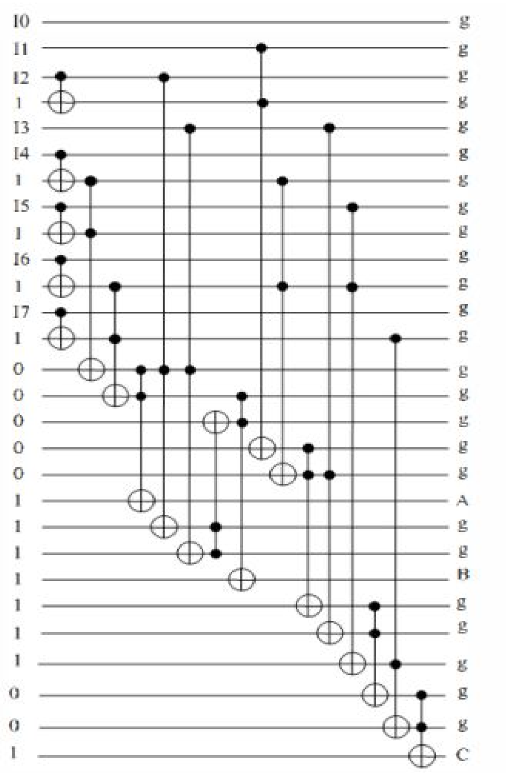

Fig. 1. Design1 D2BE.

-Number of garbage outputs: Proposed circuit consists of 12 FG gates including seven among they have one garbage output and four TKS reversible gates, each of which has two garbage outputs so NGO = 15.

-Number of constant inputs: Proposed circuit consists of 12 FG gates including two among them one constant entrance and four TKS reversible gates, each of which has one entrance constant therefore NCI = 6.

-Quantum cost: The quantum cost is not mentioned by VANDANA SHUKLA.

-Hardware complexity: The circuit contains 12 reversible gates FG and four TKS reversible gates so HC =12α + 4(2α +4β+1δ) =20α+16 β+4δ.

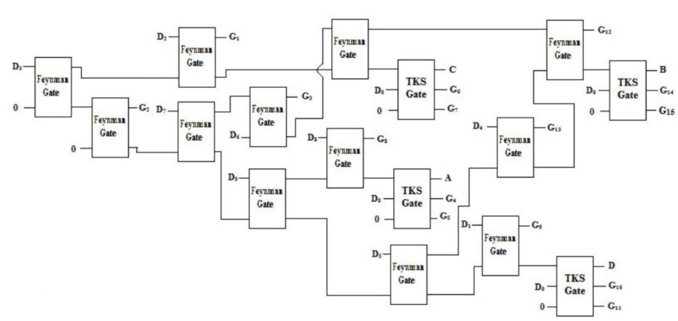

Fig. 2. Design2 D2BE.

*Design3: This design presents the decimal to BCD converter circuit design3 encoder (Fig. 3). According to this proposed circuit we have the performance criteria as follows:
-Number of gates: Its proposed circuit consists of 10 reversible BJN gates therefore CG = 10.

-Number of garbage outputs: Its proposed circuit consists of 10 BJN reversible gates of which six among them have two garbage output and three of them have one garbage output and one reversible gate BJN has no garbage output so NGO = 15.

-Number of constant inputs: The proposed circuit consists of 10 reversible gates BJN each of which has one constant input so NCI = 10.

-Quantum cost: The proposed circuit consists of 10 BJN reversible gates having QC = 50 (including QC = 5 for each) so QC = 50.

-Hardware complexity: The circuit contains 10 reversible gates BJN so HC =10α.

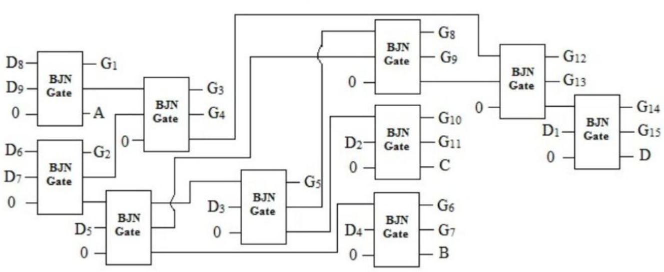

Fig. 3. Design3 D2BE.

3) Design4: In 2016 KUNAL CHAUDHARY [13] devised a design for the converter from decimal to BCD encoder is composed of four reversible gates Fredkin Gate FRG and three reversible gates FG in the following figure (Fig. 4). According to this proposed circuit we have the performance criteria as follows:

-Number of gates: CG = 11.

-Number of garbges outputs: NGO = 11.

-Number of constant inputs: NCI = 5.

-Quantum cost: QC = 23.

-Hardware complexity:The circuit contains 10 reversible gates Fredkin gate so HC =4(2α+4 β+1δ)+3α HC =11α+16 β+7δ.

4) Design5 et Design6: In 2019 SHEBA DIAMOND THABAH [14] devised two designs of the decimal converter to BCD encoder which are as follows:

*Design5: The decimal to BCD converter circuit design5 encoder as explained in Fig. 5. According to this proposed circuit we have the performance criteria as follows:
-Number of gates: Its proposed circuit consists of 10 reversible PG gates, of which therefore CG = 10.

-Number of garbage outputs: Its proposed circuit consists of 10 reversible PG gates of which five of them have two garbage output and five of them have one garbage output so NGO = 15.

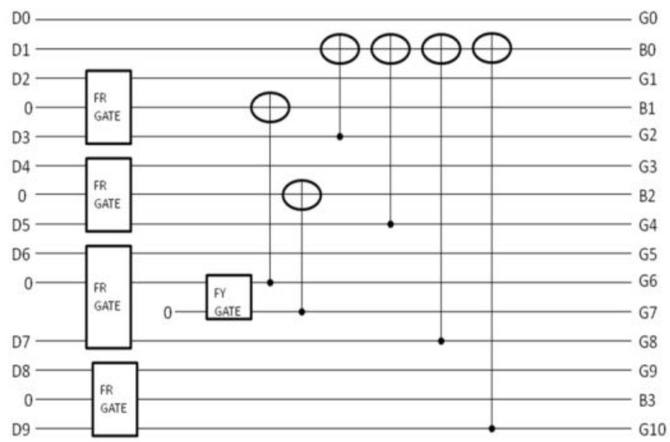

Fig. 4. Design4 D2BE.

-Number of constant inputs: Proposed circuit consists of 10 reversible PG gates of which nine of them has one constant input and the tenth has no constant input therefore NCI = 9.

- Quantum cost: Its proposed circuit consists of 10 reversible PG gates having QC = 40 (including QC = 4 for each) so QC = 40.

-Hardware complexity: The circuit contains 10 reversible gates Peres gate so: HC =10(2α+1 β) HC =20α+10 β

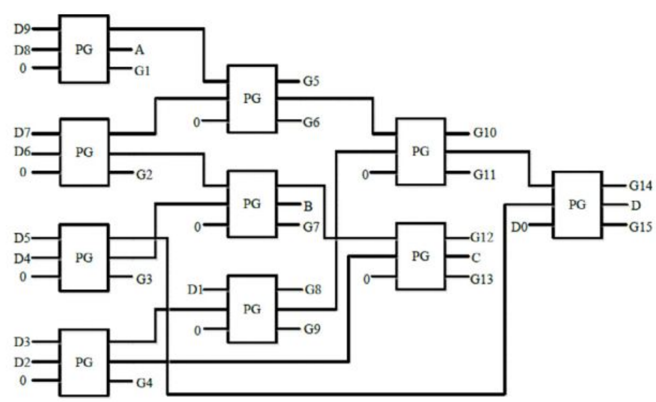

Fig. 5. Design5 D2BE.

*Design6: The decimal to BCD converter circuit design6 encoder (Fig. 6). According to this proposed circuit, we have the performance criteria as follows:

-Number of gates: Its proposed circuit consists of 11 FG reversible gates therefore CG = 11.

-Number of garbage outputs: Its proposed circuit consists of 10 FG reversible gates of which five of them have one garbage output and one of them has two garbage outputs and five among them has no garbage output so CG = 7.

-Number of constant inputs: Its proposed circuit consists of 10 reversible gates FG of which one gate among them has one constant input and the others have no constant input therefore NCI = 1.

-Quantum cost: Its proposed circuit consists of 11 FG reversible gates having QC = 11 (including QC = 1 for each) so QC = 11.

-Hardware complexity: The circuit contains 11 reversible gates of Feyman gate so HC =11(1α) HC =11α

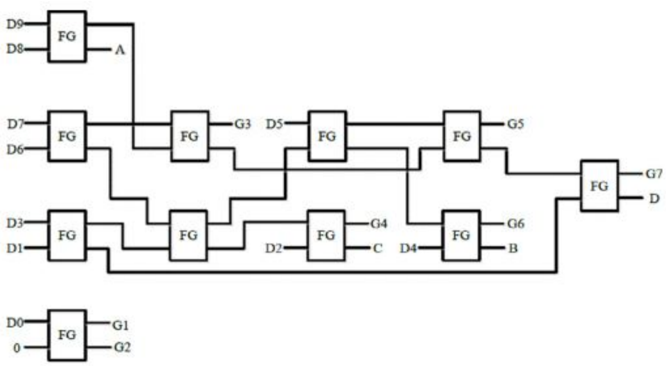

Fig. 6. Design6 D2BE.

B. Design of Reversible Binary Counter with Up/Down

It is a binary counter counting from 0 to 15 using a clock and which is linked with an up / down button that after having the impulse the counting becomes a countdown. In the following, we present the recent studies making the design of this type of binary counter.

1) Design1: IN 2016 Xuemei Q [15] proposed a design of the reversible binary counter (Fig. 7) as follows: the TFF gate is equivalent to the TFG and FG gate according to the circuit below (Fig. 8). Then based on the above we can present the performance criteria of this circuit as follows:

-Number of gates: Its proposed circuit consists of four TFF reversible gates, six gates reversible PG, three reversible gates MTG and one reversible gate FG so CG = 14.

-Number of garbage outputs: Its proposed circuit consists of three TFF reversible gates each having one garbage output, one TFF reversible gate with three garbage outputs, three reversible PG gates with one garbage output for each, three reversible PG gates with two garbage outputs for each, two reversible MTG gate with two garbage outputs for each and none of the FG reversible gates has a garbage output so NGO = 17.

-Number of constant inputs: This circuit consists of four TFF reversible gates each having two constant inputs, six reversible PG gates having one constant input for each, three MTG reversible gates with one constant inputs for each, one reversible gate FG having one constant input so NCI = 18.

-Quantum cost: Its proposed circuit consists of four TFF reversible gates having QC=24 (each of TFF composed of one TFG and one FG then we have QC (TFF) = 6 because we have QC (TFG) = 5 and QC (FG) = 1), six reversible gates PG having QC = 24 (QC = 4 for each), three MTG reversible gates having QC = 15 (QC = 5 for each), one reversible gate FG having QC = 1 therefore QC = 64.

-Hardware complexity: Its proposed circuit consists of four TFF reversible gates having HC = 16α + 4β (each of which HC = 4α + 1β because we have HC (TFG) = 3α + 1β and HC (FG) = 1α), six reversible gates PG with HC = 12α + 6β (HC = 2α + 1β for each), three reversible gates MTG having HC = 3α (each of which HC = 1α), and one reversible gate FG having HC = 1α therefore HC = 32α + 10β.

2) Design2: In 2011 V. Rajmohan [16] proposed a design of the reversible binary counter as follows (Fig. 9):

The TFF reversible gate is equivalent to the circuit below (Fig. 10). The performance criteria of this circuit as follows:

-Number of gates: The proposed circuit consists of four gates reversible TFF (each of which is made up of two SG reversible gates and one reversible gate FG), three reversible gates FRG, three reversible gates RSJ therefore CG = 18.

-Number of garbage output: Its proposed circuit consists of four TFF reversible gates, each of which has three garbage outputs (because a TFF consists of two reversible SG gates, the first gate has one garbage output and the second has two outputs and the FG gate does not have no garbage output), and the fourth gate has one more garbage output, three reversible gates RSJ each of then has one garbage output, three reversible FRG gates including two among they have one garbage output and the third has two garbage outputs so NGO = 20.

-Number of constant inputs: Its proposed circuit consists of four TFF reversible gates each having two constant inputs, six reversible PG gates having one constant input for each, three MTG reversible gates with one constant inputs for each, one gate reversible FG having one constant input so NCI = 23.

-Quantum cost: Its proposed circuit is made up of 4 reversible gates TFF having QC = 44 (because a TFF is made of two gates reversible SG and one gate FG then QC = 11), three reversible gates RSJ having QC = 36 (including each having QC = 12), three FRG reversible gates having QC = 15 (each having QC = 5) and a NOT gate we took it into consideration so QC = 96. -Hardware complexity: the proposed circuit consists of four TFF reversible gates having HC = 36 α + 32 β + 8 δ (because a TFF consists of two reversible SG gates having HC = 8 α + 8 β + 2 δ and a FG gate then HC = 1 α), three reversible gates RSJ having HC = 6 α + 3 β (each of which having HC = 2 α + 1 β), three FRG reversible gates having HC = 6 α + 12 β + 3 δ (each having HC = 2 α + 4 β + 1 δ) and a NOT bear it has been taken into consideration HC = 1 δ so HC = 48 α + 47 β + 12 δ.

3) Design3: In 2019 Mubin Ul Haque [17] proposed a design of the reversible binary counter (Fig. 11) as following:

We can present the performance criteria of this circuit as follows:

-Number of gates: Its proposed circuit consists of four reversible MSH gates, three gates reversible HNG, and one reversible gate TS-3 and a NOT gate therefore CG = 9.

-Number of garbage outputs: Its proposed circuit consists of four MSH reversible gates each of which has two garbage outputs, three HNG reversible gates, each of which has one constant input, and one reversible gate TS-3 having no constant input so NGO = 16.

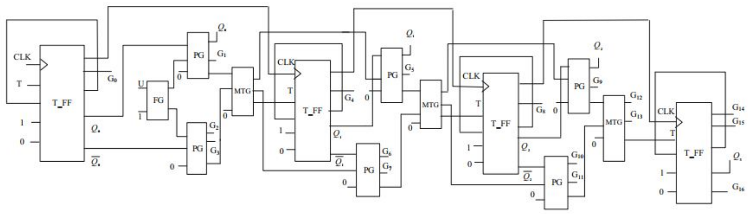

Fig. 7. Design1 Reversible 4-bit Controlled Up/Down Synchronous Counter.

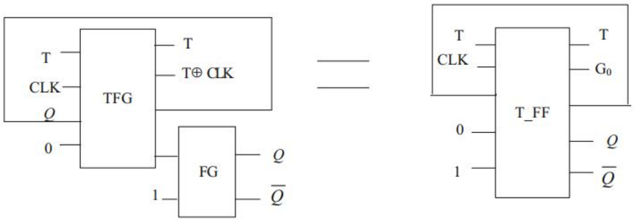

Fig. 8. Block of Reversible T Flip-flop.

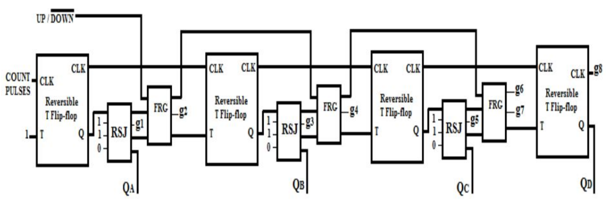

Fig. 9. Design2 Reversible 4-bit Controlled Up/Down Synchronous Counter.

-Number of constant inputs: Its proposed circuit consists of four MSH reversible gates each of which has two constant inputs, three HNG reversible gates, each of which has two garbage outputs, and one reversible TS-3 gate with two garbage outputs so NCI = 7.

-Quantum cost: Its proposed circuit consists of four MSH reversible gates having QC = 24 (of which having QC = 6), three reversible gates HNG having QC = 18 (each of which having QC = 6) and one reversible gate TS-3 QC = 2 therefore QC = 44.

-Hardware complexity: Its proposed circuit consists of four reversible MSH gates having HC = 12 α + 8 β + 4 δ (each having HC = 3 α + 2 β + 1 δ), 3 HNG reversible gates having HC = 12 α + 6 β (each having HC = 4 α + 2 β) and one reversible gate TS-3 HC = 2 α and one NOT gate having HC = 1 δ so HC = 26 α + 14 β + 5 δ.

Limitations of previous studies: We find in these previous studies a certain limitation in terms of less optimized performance criteria, the proof is that we were able to make our designs with better performance criteria than the previous works while keeping the same functionality.

IV. Our Proposed Designs

In this section, we will present our design of the converter from Decimal to BCD encoder, which we will be interested in obtaining the functional outputs which are:

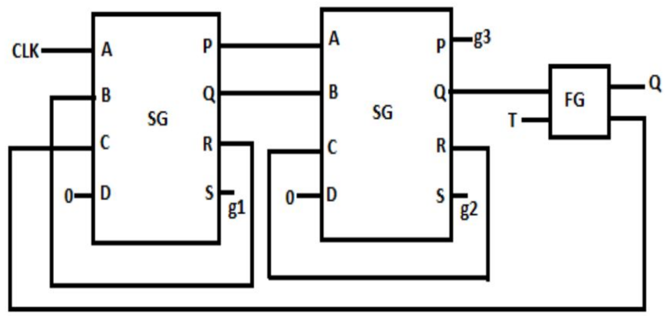

Fig. 10. Equivalent Circuit of T Flip-flop.

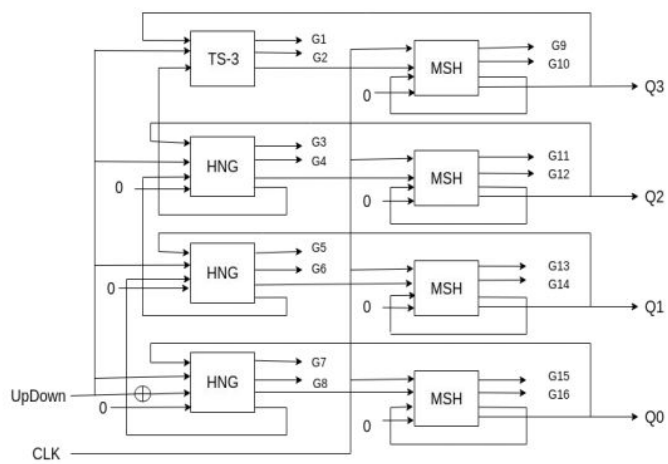

Fig. 11. Design3 Reversible 4-bit Controlled Up/Down Synchronous Counter.

$A = D8 \oplus D9$
$B = D4 \oplus D5 \oplus D6 \oplus D7$
$C = D2 \oplus D3 \oplus D6 \oplus D7$
$D = D1 \oplus D3 \oplus D5 \oplus D7 \oplus D9$
Our design is consisting of five HNFG reversible gates. Fig. 12 present our proposed circuit and its performance criteria:

* Number of gates: We have five reversible gates of the HNFG so CG = 5.

* Number of garbage outputs: Our design has the same functional outputs showed above. Concerning the garbage outputs, based on the functions of the reversible gates are as follows: G1 = D9, G2 = D1, G3 = D5, G4 = D9$\oplus$D7, G5 = D7$\oplus$D6 Then NGO = 5.

* Number of constant inputs: We notice that there is no

constant input therefore NCI = 0.

* Quantum cost: We have five reversible gates of the HNFG so QC = 10 (QC = 2 for each gate).

-Hardware complexity: The proposed circuit consists of five reversible HNFG gates having HC = 10 α (each of which having HC = 2 α).

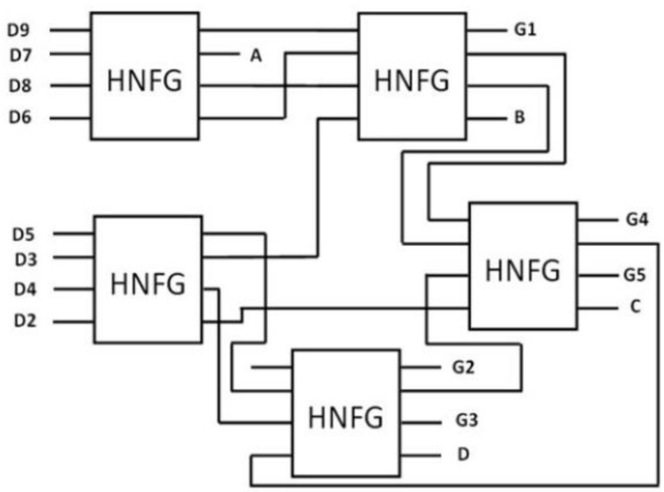

Fig. 12. Our Design of the Converter from Decimal to BCD Encoder orD2BE.

And in the other hand, we will present our proposed circuit of the reversible binary counter by showing its performance criteria while revealing the improvement percentages in terms of these parameters compared to three recent designs. Based on the circuit of [17], we replace the reversible gate MSH by the reversible gate NP since they have the same functional outputs (third and fourth output) if we fix the fourth entry by 0, by the following, we obtain below our circuit (Fig. 13). Then based on our proposed design we can present the performance criteria of this circuit as follows:

-Number of gates: Its proposed circuit consists of four NP reversible gates, three reversible gates HNG, and one reversible gate TS-3 and a NOT gate therefore CG = 9.

-Number of garbage outputs: The proposed circuit consists of four NP reversible gates each of which has two garbage outputs, three HNG reversible gates, each has one constant input, and one reversible gate TS-3 having no constant input so NGO = 16.

-Number of constant inputs: The proposed circuit consists of four NP reversible gates each of which has two constant inputs, three HNG reversible gates, each of which has two garbage outputs, and one reversible TS-3 gate with two garbage outputs so NCI = 7.

-Quantum cost: the proposed circuit consists of four NP reversible gates having QC = 20 (of which having QC = 5), three reversible gates HNG having QC = 18 (each of which having QC = 6) and one reversible gate TS-3, QC = 2; therefore QC = 40.

-Hardware complexity: The proposed circuit consists of four NP reversible gates having HC = $12\alpha + 16\beta + 8\delta$ (each of which having HC = $3\alpha + 4\beta + 2\delta$), three reversible gates HNG having HC = $12\alpha + 6\beta$ (each of which has HC = $4\alpha + 2\beta$) and one reversible gate TS-3 HC = 2α and one NOT gate having HC = 1δ so HC = $26\alpha + 22\beta + 9\delta$.

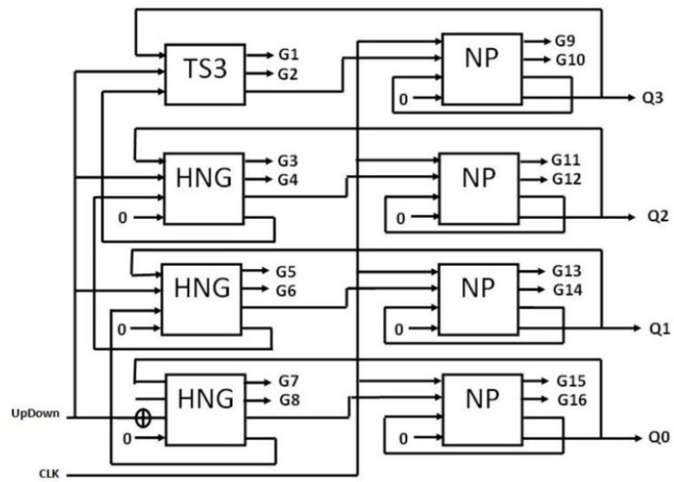

Fig. 13. Our Design of Reversible Binary Counter with Up/ Down.

V. Results and Discussion

So in this section, we will compare our results obtained compared to recent studies of the D2BE converter circuit and those of the reversible binary counter.

Regarding the first circuit, we will draw up a comparative table, that is, Table II showing performance criteria.

TABLE II. Comparative Table of Performance Criteria for Recent Designs of D2BE and our Improvements Obtained

Circuit D2BE	CG	NGO	NCI	QC	HC
Our design	5	5	0	10	10α
Expolited design1 [11]	20	25	—	80	$20\alpha + 15\beta$
Expolited design2[12]	16	15	6	—	$20\alpha + 16\beta + 4\delta$
Expolited design3[12]	10	15	10	50	10α
Exploited design4[13]	11	11	5	23	$11\alpha + 16\beta + 4\delta$
Exploited design5 [14]	10	15	9	40	$20\alpha + 10\beta$
Exploited design6[14]	11	7	1	11	11α
%Imp (Design1)[11]	75	80	—	87,5	50CNOT ,100AND
%Imp (Design2) [12]	68,75	66,67	100	—	50CNOT, 100AND 100NOT
%Imp (Design3)[12]	50	66,67	100	80	no improvement is obtained
%Imp (Design4)[13]	54,54	54,54	100	56,52	9,09CNOT,100AND , 100NOT
%Imp (Design5)[14]	50	66,67	100	75	50CNOT 100AND
%Imp (Design6)[14]	54,54	28,57	100	9,09	9,09CNOT

So in this section, we will compare our results obtained compared to recent studies of the D2BE converter circuit and those of the reversible binary counter.

For the design:

-Design1 [11]: 75%, 80%, 87.5% ,50%, 100% in terms of CG, NGO, QC, CNOT, ND, respectively. -Design2 [12]: 68.75%, 66.67%, 100%, 50%, 100%, 100% in terms of CG, NGO, NCI, CNOT, AND, NOT, respectively.
-Design3 [12]: 50%, 66.67%, 100%, 80% in terms of CG, NGO, NCI, QC, AND, respectively.

-Design4 [13]: 54.54%, 54.54%, 100%, 56.52%, 9,09%, 100%, 100% in terms of CG, NGO, NCI, QC, CNOT, AND, NOT, respectively. -Design5 [14]: 50%, 66.67%, 100%, 75% and 50%, 100% in terms of CG, NGO, NCI, QC, CNOT, AND, respectively.
-Design6 [14]: 54.54%, 28.57%, 100%, 9.09%, 9.09% in terms of CG, NGO, NCI, QC, CNOT Deadline, respectively.

We will present the following graph of performance criteria of D2BE designs shown in Fig. 14.

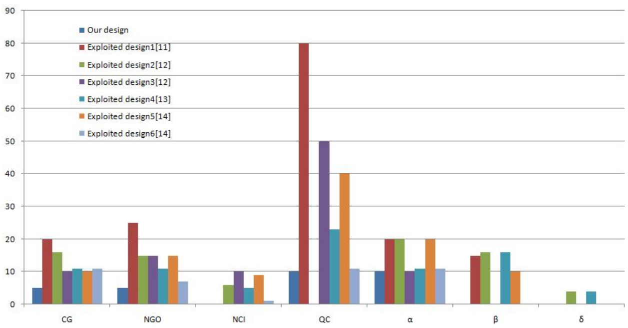

Fig. 14. Performance Criteria of D2BE Designs.

Then concerning the reversible binary counter circuit and According to the recent designs mentioned below and their performance criteria and according to our proposed design we can draw up the following comparative table (Table III).

TABLE III. Comparative Table of Performance Criteria for Recent Designs of Reversible Binary Counter with Up/ Down and our Improvements Obtained

Binary reversible counter	CG	NGO	NCI	QC	HC
Our design	9	16	7	40	$26\alpha+22\beta+9\delta$
Exploited Design 1 [15]	14	17	18	64	$32\alpha+10\beta$
Exploited Design2 [16]	18	20	23	96	$48\alpha+47\beta+12\delta$
Exploited Design3 [17]	9	16	7	44	$26\alpha+14\beta+5\delta$
%Imp [15]	35,71	5,88	61,11	37,5	18,75 CNOT
%Imp [16]	50	20	69,56	58,33	45,83 CNOT,53,19AND et 25 NOT
%Imp [17]	—	—	—	9,09	no improvement is obtained

According to this table we were able to improve the performance criteria in our proposed design compared to six recent designs as follows: For the design:

-Design1 [15]: 35.71%, 5.88% and 61.11%, 37.5%, 18.75% in terms of CG, NGO, NCI, QC, number of CNOT gates, respectively.

-Design2 [16]: 50%, 20% and 69.56%, 58.33%, 45.83%, 53.19%, 25% CG, NGO, NCI, QC, number of CNOT gates, number of CNOT gates number of AND gates and number, number of NOT gates. NOT gates, respectively.

-Design3 [17]: 9.09% in terms of QC.

According to these results obtained, they are represented in the graph below (Fig. 15).

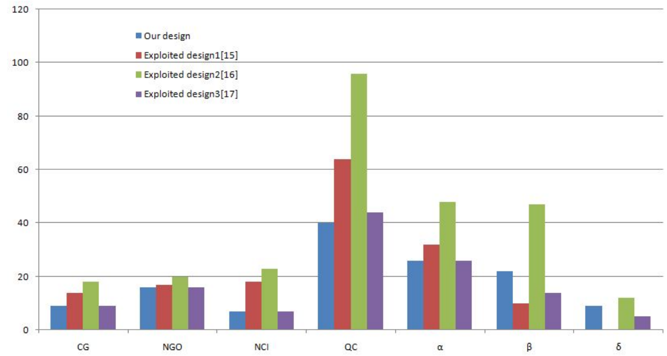

Fig. 15. Performance Criteria of Reversible 4-bit Controlled Up/Down Synchronous Counter Design.

VI. Conclusion

Reversible logic occupies a significant role in reducing energy loss at the end of unused bits in the circuit compared to conventional logic computation. Our design was able to minimize all performance criteria especially the number of garbage outputs in our D2BE circuit and the reversible binary counter,as a result a decrease in the energy dissipated at the end of unused bits because heat is directly related to fewer garbage outputs, therefore our designs are adequate for low power application. We show also an improvement in terms of other performance criteria exposing remarkable results. While waiting for new reversible gates to exploit in the future, we can optimize the D2BE circuit and that of the reversible binary counter respecting the performance, typically concerning minimizing heat energy.

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Financial Stumbling Detection Model for SMEs

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***Abstract*—Access to financing is still one of the greatest obstacles facing Small and Medium Enterprises (SMEs) all over the world and prevents them from developing. Because a large percentage of these projects fail/stumble and go bankrupt, due to failures in their financial management and assets management decisions. SMEs do not only play an important role in the global economy but also it is one of the sources of social stability and an effective role in a country's economy. The previous researches indicate that BI systems are mainly applied in large enterprises, but using BI in SMEs is very rare. Thus, to enhance financial decisions, the study uses various ICT tools such as business intelligence (BI). This research develops a Financial Stumbling Detection (FSD) Model using BI that can help SMEs stakeholders in taking the proper financial decisions. The FSD model identifies the initial stumble/defect in SMEs, by using some financial ratios. And it was created relying on Design Science Research (DSR) methodology. The results of using BI in SMEs give the necessary insight into a business's financial data, and highlight if the business is heading for a financial crisis and potential failure.**

Keywords—SMEs; financial statements; business intelligence (BI); DSR methodology; financial decisions

I. Introduction

Nowadays Small businesses are the main pillar of economic development in Egypt, and a strategic goal adopted by the Egyptian state, because of its vital role in the development and reducing unemployment, so the orientation of medium, small and micro business has become the largest engine for economies to achieve sustainable development.

In Egypt, there are nearly 2.5 million SMEs that secure about 75% of total job opportunities and represent around 99% of the non-agricultural establishments of the private sector [1], According to Fifth Economic Census (2017/2018), the number of SMEs in Egypt increased to 365.3 million establishments in the last 5 years. It represents more than 80% of the Egyptian economy's structure. In addition, SMEs are vital for promoting exports, enhancing competitiveness, and fostering innovation [2]. Egypt Vision 2030 is based on three pillars: a vibrant society, a thriving economy, and an ambitious homeland. Our economy needs a prosperous and attractive to be developed for improving investment, increasing productivity, enhancing competitiveness, and shifting from consumption to production. This is required to increase the number of small and medium enterprises, encouraging young people for entrepreneurship, stimulate innovation and creativity, to focusing on industrial and technological sectors instead of all domestic projects for commercial areas. This service is creating a kind of repetition that is not attractive because diversity is important for progress and achieving economic development.

SMEs face many challenges that lead to bankruptcy and failure. As Harraf [3] said because of the fast rate of technological transitions creates the source of uncertainty, competitive intensity, and global competition for businesses. The most important challenges SMEs faced which led to the failure of the alignment process are the lack of conscious planning, lack of strategic decision making, and sharing information [4]. Most of the problems faced SMEs because of decision making which is defined as the selection of action and method managers/organizations use to conduct the changing environment associated with speedy responsiveness [5].

Paper structure: The problem definition will be discussed in the next Section II, then in Section III the related work will presented. The research methodology will be introduced in Section IV. The development will be covered in Section V after that the evaluation will illustrated in Section VI. Last but not least the conclusion will summarize in Section VII.

II. Problem Definition

A large percentage of the failure/stumble and bankruptcy of these projects is due to a failure in their financial management and asset management decisions. Indeed, it is important to understand the decision environment for the effectiveness of the decision making, because it is considered as the source of the decision problem, decision goals, and relevant resources [6]. Therefore, businesses are increasingly and largely depending on the adequacy and accuracy of the information supply chain [7]. Although it has been recognized for its decision-making effectiveness, the study raises a concern to conduct information management in businesses. In order to increase SMEs ' resilience in times of crisis, and increase their response time to market changes, SMEs started to use various ICT tools, such as business intelligence (BI) and business process management (BPM). Despite this, previous research indicates that BI and BPM systems are mainly applied in large enterprises, while BI and BPM practices in SMEs are very low [8][9]. Researchers claim that the alignment between organizational perspectives such as strategy, structure, management processes, individual roles, and skills with technology can help to increase value in businesses, IS effectiveness, and business performance [10].

III. Related Work

Both Pina [11] and Bosire [12] highlight the key role that BI tools play in effectively managing information in business. The successful implementation of BI tools can ensure that management benefits from improved access to up-to-date and accurate information when desired. These tools can provide strategic management and other stakeholders with a complete overall view of the business, thus providing benefits such as the ability to enable more reliable, faster, and more accurate decisions [13]. Therefore, organizations require assimilating and processing information for detecting the degree of effects of those changes that may help organizations to take the dynamic decision [5]. According to Adeyelure [14] organizational factors e.g. top management support, management expectations, and financial resources, are the most pertinent in the implementation of BI in SMEs. On the other hand, the prevalence of the functional organizational structure of SMEs negatively affects the implementation of the process-oriented approach [15]. SMEs reaped many benefits from the existence of BI such as efficiency. Raj et al. [16] in 2016 overcome their finds about the challenges in SMEs by developing BI tools that provide analytical data and KPIs that ensure SMEs to be managed efficiently. Raj, et al. [17] 2019 enhance his model by involving in knowledge management and discovery, helping the business to overcome its challenges. Gauzelin and Bentz [18] employ BI in SMEs to facilitate timely decision making, enable the company to meet client's needs appropriately, and lead to employees' satisfaction. Gudifinnsson and Strand [19] developed a model that enforces a change in processes and added new KPIs to ensure business efficiency. Llave [9] highlight the importance of BI in SMEs proposed a modified BI&A value creation framework for SMEs with an automated data warehouse approach. Furthermore, pulled [20] develops and tests a model to act as a solution provider and to provide instrumental insights for managers helping them increase their business efficiency.

IV. Research Methodology and Case Study

DSR Methodology was the underlining research methodology followed in the large study [21] [22], which followed in this study.

The FSD model is developed to help SMEs in their financial decisions and to address problems with strategic financial information management. An extensive literature study was conducted to drive the theoretical framework. The proposed BI framework integrated with 6 steps of the model created using DSR. Steps:

- Awareness of problem.
- Suggestion.
- Set indicators.
- Collect data and information based on indicators.
- Development.
- Evaluation.

The knowledge gained throughout accumulative stages in DSR laid the foundation for understanding the analysis of requirements for creating the suggested FSD Model.

In conjunction with DSR, case studies were used; there were eighteen case studies for eighteen different businesses. Two of them will be discussed in this paper.

A. *Awareness of Problem*

This has been illustrated in the introduction and problem definition sections.

B. *Suggestion*

This phase started with a number of interviews which were conducted with stakeholders of the businesses. These interviews result and some collected data from the findings of the literature review would be constructing the BI to articulate their requirements and establish the KPIs that are required to measure SME's financial performance. The main challenges were identified and the initial image of the desired model was set. Using this information, the business can continuously make decisions to determine if it is on the right track to meet its long-term goals or not. The initial requirements to build this model are as follows:

1) Ratios that helps in showing if the business is on right track or not are illustrated in Index 1 & 2 at Table I in Fig. 1 [27]:

a) Financial structure of the business: The financial structure instability is evidence of failure symptom [23], showing that if there was an efficiency or a defect in the financial structure in the business, by checking these two conditions:

i) Fixed assets (FFA) ≤ long term liab. + OE.

ii) Current assets (FCA) ≤ short term liab. + OE.

b) Profitability Ratios: Showing the business's efficiency in obtaining the appropriate profitability in relation to the size of its Assets, Sales, Equity and Investments or not by calculating four main ratios [24][26]:

i) ROS = Net Income \ Net Sales.

ii) ROA =Net Income + Interest expense \ average assets.

iii) ROE =Net Income \ average owner's equity.

iv) ROI =Net Income \ average investments.

c) Debt Ratios: The strength of the business's ability or inability to meet its long-term liabilities by calculating two main equations [25] [26]:

i) Debt Ratio (D.R) = total liabilities \ total assets.

ii) Times-interest-earned Ratio (TIE.R) = income \ interest expense.

d) Activity Ratios: Showing the business's efficiency/inefficiency in managing its inventory and account receivables by calculating two main equations [26]:

i) Inventory turnover (ITO) = cost of sales \ average inventory.

ii) Accounts Receivables turnover (A\RTO) = Net sales \ average A\R.

e) Risk Ratios: Showing the business's initial risk if existed [27].

i) Operational risk ratio (ORR): ΔTotal income \ Δsales.

ii) Financial risk ratio (FRR): ΔNet revenue \ Δtotal income.

iii) Total risk ratio (TRR): Δ Net revenue \ Δ sales.

f) Liquidity Ratios: Showing if the business has the efficiency in paying its current liabilities from the current assets or needed to sell from its fixed assets to pay off its liabilities, using the following four equations [26]:

i) Working capital (LWC): Current assets – Current liabilities.

ii) Current ratio (LCR): Current assets \ Current liabilities.

iii) Quick ratio (LQR): Cash + Account receivables \ Current liabilities.

iv) Total coverage (LTC): Revenue before interest \ Interest expense.

2) Industry ratios: An aggregate measure of industry performance. Publishers gather data from the financial statements of hundreds of firms to calculate industry averages. Often they break out the results into categories based on the asset size of the companies. These are then used as a benchmarking tool in comparing a company's performance to that of its industry. Industry ratios used in this example are according to the Financial and statistical report of the General Authority for Investment and Free Zones (GAFI), for the two fiscal years 2017, 2018[27].

C. Set Indicators as a KPIs

Referring to Table I:

In Index 2, highlights the equations from 1 to 17 previously defined. The key performance indicators (KPIs) for business are setting after the process the required ratios to act as a condition as follow:

- If calculated ratio increased from year to another?
- If calculated ratio greater than or equal to the industry ratios?

In index 3 the result of answering KPIs Questions of each ratio were recorded as follow:

1. True (√) if the condition was verified.
2. False (X) if the condition not verified.

The datatype format of output results is different from each other, such as integers, float, and Boolean. Thus, putting a weight for each calculated value standardized the output value. By weighting the results in Index 3, each ratio will have a weighted value. These weighted values are categorized into 3 values (0, 1, and 2) defined as follow:

Value2 = If the two conditions were verified (fulfilled) (T\T).

Value1 = Only one condition was verified (fulfilled) (T\F) (F\T).

Value0 = None of the conditions were met (F\F).

Index 4, the way of distribution of the weights for financial structure, liquidity, activity, and risk ratios are according to the output. The output is processed information from the weighting of any candidate SME, to be checked against the KPIs applied for all Targeted Data.

Referring to Table I:

**The weight of the current ratio in the liquidity ratios is multiplied by 2 because it has a double effect on the liquidity ratios.

* There were some special cases that must be smaller than the industry ratios and must be decreased from one year to another such as debt ratio and risk ratios, therefore interpreting the weights evaluation values is inverted [25].

TABLE I. OF FSD MODEL

Index	Processing			Financial Ratios																
1	Target data	Calculated Ratios		Financial structure		Liquidity ratios				Debt ratios		Profitability ratios				Activity ratios		Risk ratios		
2				FFA	FCA	LWC	LCR	LQR	LTC	D.R	TIE.R	ROS	ROA	ROE	ROI	ITO	A/RTO	ORR	FRR	TRR
3	*Indicators (KPIs)	Conditions	↑ from year to another	-	-	√	√	√	√	X	√	√	√	√	√	√	√	X	X	X
			≥ Industry Ratio	-	-	-	√	√	√	X	√	√	√	√	√	√	√	X	X	X
4	**Computing	Weights		2 1 0		1 0	4 2 0	2 1 0	2 1 0	0 1 2	2 1 0	2 1 0	2 1 0	2 1 0	2 1 0	2 1 0	2 1 0	0 1 2	0 1 2	0 1 2
5	Clustering	Matrix		2,1,0 2 → Max. weight 0 → Min. weight		0,1 | 0,2,4 | 0,1,2 | 0,1,2 9 → Max. weight 0 → Min. weight				0,1,2 | 0,1,2 4 → Max. weight 0 → Min. weight		2,1,0 *For each one 2 → Max. weight 0 → Min. weight				0,1,2 | 0,1,2 4 → Max. weight 0 → Min. weight		0,1,2 | 0,1,2 | 0,1,2 6 → Max. weight 0 → Min. weight		
6	Descriptive knowledge	The Results		The Results will be explain in depth in Table 2																

D. Collect Data and Information based on Indicators

The weighted results for each financial ratio in Index 1 were set in a one-dimension matrix. Referring to Iindex 4, then these values are summed to get one value per financial indicator. Using a division Hierarchical Clustering, the weight obtained from the matrix is classified into groups. Each weight has a different justification, which helps the user in making financial decisions. These weights clustering are presented in Table II. Example on applying a division Hierarchical Clustering on liquidity ratios shows how the FSD model acquires the weight for each equation as shown in Fig. 2.

In the same way, the division cluster is applied to debt, profitability, activity, and risk ratios and to the financial structured.

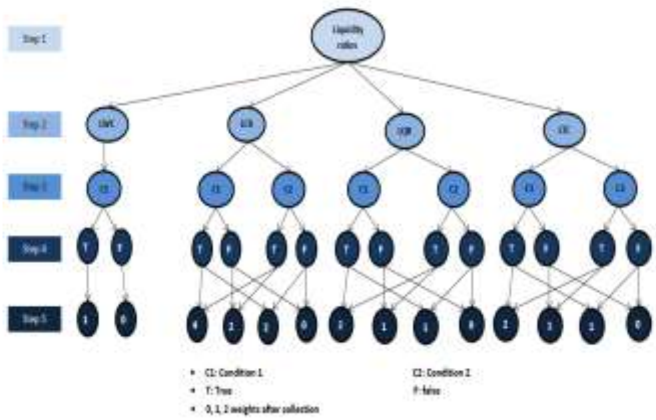

Fig. 1. Appling Division Clustering.

V. Development

As there are different tools available for implementing a BI solution, we decided to use the Microsoft suite of BI tools, which facilitates a seamless integration of IT infrastructure. The various components on a Microsoft SQL Server supported our implementation of the BI solution such as:

- SQL Server Database Engine: This includes the Database Engine, storing, processing, and securing.
- Analysis Services: This includes the tools for creating and managing data mining applications.
- Reporting Services: This includes server and client components for creating, managing, and deploying reports.
- Power BI services: This includes the visualizing of final reports.

As shown in Table II, a condition will be applied on Profitability, Debt, and activity ratios due to the two different justifications at a specific weight. In other words, depending on the interruption of the conditions as below:

- Profitability at weight 1: This means one out of two KPIs conditions was fulfilled. It will have a justification, if the fulfilled condition was "If calculated ratio greater than or equal to the industry ratios?" And a different justification if this condition is not met.
- At Debt at weight 2: It has two different justification based on the result from each calculated ratio. If the results of preprocess data are not equal to zero in one of the calculated ratio's weights have a justification differ from if not.
- As the same as in debt weight at 2, the same at activity weight at 2.

The biggest weight for each financial ratio differs from one to another, for example:

- Financial structure and profitability ratios (ROA, ROE, ROS, and ROI) highest weight is 2, which represents 100% on the graph presentation for these ratios.
- Debt and Activity ratios highest weight is 4, which represents 100% on the graph presentation for these ratios.
- By the same way the risk ratio highest weight is 6 and liquidity ratio's is 9.

Two case studies will be used to illustrate the working mechanism of this model in detecting the initial financial stumble in SMEs.

TABLE II. JUSTIFICATION FOR WEIGHTS CLUSTERS AT FSD MODEL

Index	**1**	**2**	**6**	
Processing	**Calculated ratios**		**Matrix Weights**	**Justifications**
Financial Ratios	Financial structure	FFA & FCA	2 1 0	The efficiency of the financing structure. The financing structure needs to be modified. A defect in the financing structure
	Liquidity ratio	LWC, LCR, LQR & LTC	7,8,9 5,6 0,1,2,3,4	It has the efficiency of paying its current liab. From the current assets (perfect). The company has to review the size of its liquidity. The inability of the company to pay its current liab. Without the need to sell from its fixed assets.
	Debt ratio	D.R & TIE.R	3,4 2 0,1,2 ? (yes) (No)	The strength of the company's ability to meet its long-term liab. The company should review its borrowing policy. The inability of the company to pay off its long-term liab.
	Profitability ratio	ROS, ROA, ROE & ROI	2 1 0 ? (yes) (No)	The company's efficiency in obtaining the appropriate profitability in relation to the size of its (Assets OR Sales OR Equity OR Investments). Despite the decreases in the value of the profitability index, it is still within the limits of the industry ratios. In the correct direction, it will be increased up to the industry ratios. The inefficiency of the company in obtaining the appropriate profitability in the relation to the size of its (Assets OR Sales OR Equity OR Investments).
	Activity ratio	ITO & A/RTO	3,4 2 0,1 ? (yes) (No)	The company's efficiency in managing the inventory and A\R. The company should review its inventory and A\R policies. The company has stumbled on inventory OR A\R management. The inability of the company to manage its inventory and A\R.
	Risk ratio	ORR, FRR &TRR	5,6 4,3 0,1,2	The company has no risk. The company has moderate risk. The company has a high risk (very risky).

VI. EVALUATION

A. Case Study 1 (ABC Company)

The financial statements of the company for two fiscal years are used to calculate the financial ratios needed in the FSD model according to Indexes 1 and 2 in Table I.

After Appling FSD Model on ABC Company, the model illustrates that referring to Table III:

1) At Index 2 FFA and FCA in the financial structure, the two conditions were fulfilled in Index 3, so referring to index 4 FFA and FCA had weighted with value 2 out of 2 which shows in Fig. 2 100%. So the model can illustrate that the Company has efficiency in its financial structure according to the justification of the resulted weight.

TABLE III. AFTER APPLIED FSD MODEL ON ABC COMPANY

Index	processing		Financial Ratios																
1	Calculated Ratios (Industry Ratio)		Financial structure		Liquidity ratios				Debt ratios		Profitability ratios				Activity ratios		Risk ratios		
2			FFA	FCA	LWC	LQR (0.4)	LCR (1.7)	LTC (4.1)	D.R (0.64)	TIE.R (2.3)	ROS (1)	ROA (4.2)	ROE (12.1)	ROI (0.1)	ITO (3)	A/RTO (11.7)	ORR (0.1)	FRR (15.5)	TRR (0.35)
	Calculated values		TRUE	TRUE	110000 120000	2018 0.93 2019 1.01	2018 1.85 2019 1.87	2018 4.66 2019 4.58	2018 0.50 2019 0.55	2018 4.07 2019 4.21	2018 3.2 2019 5.6	2018 6.2 2019 10.1	2018 8.1 2019 14.2	2018 0.14 2019 0.26	2018 4.54 2019 4.6	2018 8.07 2019 8.6	2018 0.032 2019 0.056	2018 11.31 2019 7.19	2018 0.37 2019 0.4
3	Conditions	↑ from year to another	-	-	√	√	X	X	√	√	√	√	√	√	√	√	√	X	√
		≥ industry ratio	-	-	-	√	√	√	X	√	√	√	√	√	√	X	X	X	√
4	Weights		T/T 2		T 1	T/T 2	F/T 2	F/T 1	F/T 1	T/T 2	T/T 2	T/T 2	T/T 2	T/T 2	T/T 2	T/F 1	F/T 1	F/F 2	T/T 0
5	Matrix		[2] Weight =2		[1 2 2 1] Weight = 6				[1 2] Weight = 3		[2] Weight = 2 for each one				[2 1] Weight = 3		[1 2 0] Weight = 3		

2) In profitability ratios (ROA, ROS, ROE, and ROI) the two conditions in Index 3 were fulfilled for each ratio. So it weighted in Index 5 to be 2 out of 2 which is shown in Fig. 2 100%, which is justified as it has efficiency in obtaining the appropriate profitability in relation to the size of its Assets, Sales, Equity, and Investments.

3) In the Liquidity Ratios, only 1 KPIs condition was fulfilled for LCR & LTC referring to index 3. So with referring to index 5 the total weights of this ratio have become 6 out of 9 which is shown in Fig. 2, 66.67%, which is justified as The company has to review the size of its liquidity.

4) Inactivity ratios, the 2 KPIs conditions were fulfilled at ITO, and only 1 KPIs condition was fulfilled at A\RTO referring to Index 3. So the activity ratios had weighted with value 3 out of 4 which is shown in Fig. 2, 75%. This is justified as it has a strength of ability to meet its long-term liabilities and has efficiency in managing its inventory and A\R.

5) In risk ratios, the model illustrated that there is a moderated risk in this company. Because referring to Index 3 in ORR only 1 KPIs condition was fulfilled and in TRR there were no condition was meet. So Risk ratio was weighted to be 3 out of 6 which is shown in Fig. 2, 50%.

Using Visualization, the overall view of ABC Company is followed in Fig. 2:

The graph illustrates that:

The company has efficiency in its financial structured, but it has to review the size of its liquidity. It has also the strength of ability to meet its long-term liabilities and efficiency in obtaining the appropriate profitability in relation to the size of its Assets, Sales, Equity, Investments, and in managing its inventory and A\R. Although the company's indicators all indicate that it is on right track, it has a moderated risk factor.

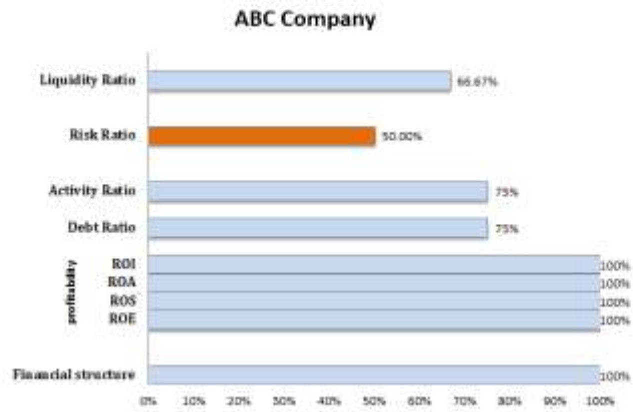

Fig. 2. ABC Company Visualization.

B. *Case Study 2 (XYZ Company)*

After appling FSD model on XYZ Company, the initial financial defects (stumbles) of the company which leads to being under shutdown are illustrated in Table IV as the following:

1) The company's financial structure needs to be modified, referring to Index 2 in Table IV, FFA ≤ long-term liab. + owner's equity but FCA > short-term liab. + Owner's equity, which means that was only one KPIs condition was fulfilled, thus it takes 1 out of 2 in the total weight, which is shown in Fig. 3 as 50%.

2) In the liquidity ratio only one KPIs condition was fulfilled in LTC that weighted of value 1, there was no condition was meet in LCR, only LQR had the 2 conditions fulfilled as shown in Index 3. Referring to Index 5 the total concluded weight for this ratio was 3 out of 9, which shows in Fig. 3 as 33.33%. this means the inability of the company to pay its current liabilities without the need to sell from its fixed assets.

TABLE IV. AFTER APPLIED FSD MODEL ON XYZ COMPANY

1			Financial structure		Liquidity ratios				Debt ratios		Profitability ratios				Activity ratios		Risk ratios		
2	Calculated Ratios		FFA	FCA	LWC	LQR (0.4)	LCR (1.7)	LTC (4.1)	D.R (0.64)	TIE.R (2.3)	ROS (1)	ROA (4.2)	ROE (12.1)	ROI (0.1)	ITO (3)	A/RTO (11.7)	ORR (0.1)	FRR (15.5)	TRR (0.35)
3	Conditions	↑ from year to another	True	False	X	√	X	X	√	X	X	X	X	X	X	√	√	X	√
		≥ industry ratio			-	√	X	√	X	X	√	X	√	√	X	X	√	√	√
4	Weights		T/F 1		F 0	T/T 2	F/F 0	F/T 1	F/T 1	F/F 0	F/T 1	F/F 0	F/T 1	F/T 1	F/F 0	T/F 1	T/T 0	F/T 1	T/T 0
5	Matrix		[1] Weight = 1		[0 2 0 1] Weight = 3				[1 0] Weight = 1		Weight = 1 for ROS, ROE and ROI = 0 for ROA				[0 1] Weight = 1		[0 1 0] Weight = 1		

3) In debt ratios No conditions were meet in D.R, and only one condition was fulfilled in TIE.R. Referring to Index 5, the concluded weight value was 1 out of 4 which shows in Fig. 3 as 25%, which means the inability of the company to pay-off its long-term liabilities.

4) In profitability ratios, ROE, ROS, and ROI have only one KPIs condition that was fulfilled. Thus it takes 1 out of 2 in the total weight, which is shown in Fig. 3 as 50%. Justified "Despite the decreasing in the value of the profitability index of ROE, ROS, and ROI, there are still within the limits of the industry ratios". In ROA no KPIs condition was meet, so the company has inefficiency in obtaining the appropriate profitability in the relation to the size of its Assets which is shown in Fig. 3 as 0%.

5) Inactivity ratios, there was no KPIs condition was meet in ITO, and only one condition was met in A\RTO. Referring to Index 5, it takes 1 out of 3 in the total weight, which shows in Fig. 3 as 25%. That means the inability of the company to manage its inventory and A\R.

6) In Risk Ratio It was justified as it has a high risk (very risky), because the ratio of ORR & TRR increased from one year to another despite it must be decreased, and their values bigger than the industry ratios even though it must be smaller than or equal to industry ratio. That means there was no condition was meet in these ratios. And in FRR only one condition was fulfilled, referring to Index 5 the total weight equal to 1 out of 6 which is shown in Fig. 3 as 16.6%.

Using Visualization, the overall view of ABC Company is followed in Fig. 3:

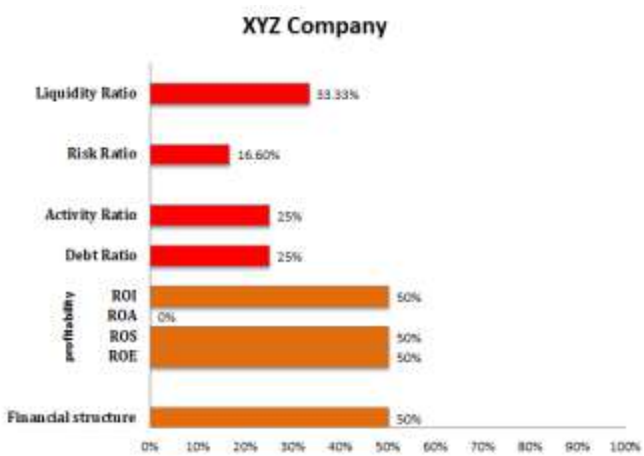

Fig. 3. XYZ Company Visualization.

Graph visualizes a summary of the resulted outcome of the model that illustrates:

The company's financial structure needs to be modified. And it has the inability to pay its current liabilities without the need to sell from its fixed assets and to pay off its long-term liabilities. Also, it had inefficiency in obtaining the appropriate profitability, cannot manage its inventory and A\R. Also, it has high risk (very risky).

VII. Conclusion

Many challenges faced the researcher, from the difficulty in taking the permissions to make the interviews with the stockholders of SMEs, to the difficulty in getting the financial statements from the businesses. But all of these challenges have been successfully overcome.

Several limitations should be taken into account when evaluating the results of our research; we conducted empirical research in SMEs in Egypt only, on a relatively small sample, based on a cross-sectional approach additional sources of information could be used, such as cash flow statements and other financial indicators from official financial reports.

This work has been applied to eighteen cases studies on that model, the visualization results of the applied cases ensure that:

1) The ratio that weighted less than 50% has a defect/stumble on its structure or policies.

2) If more than three ratios out of six have a defect of less than 50% we can conclude that the company may be to be under the shutdown.

The user of financial background or SMEs stakeholder can indicate the stumbling reason of the company after seeing the visualization graph, knowing why was the company was under shutdown? Where was the defect?

The empirical FSD model proves its worth in identifying the initial stumble/defect in SMEs, using some financial ratios, by testing the concluded KPIs on the targeted data.

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